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DIAGNOSIS OF SURFACE WEATHER CONDITIONS FROM OBSERVED AND PROGNOSTIC UPPER-AIR PARAMETERS

Russell G. Harris
Joseph G. Bryan
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February 1965

433L SYSTEMS PROGRAM OFFICE
ELECTRONICS SYSTEMS DIVISION
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L. G. Hanscom Field, Bedford, Mass.

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FOREWORD

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DIAGNOSIS OF SURFACE WEATHER
CONDITIONS FROM OBSERVED AND
PROGNOSTIC UPPER-AIR PARAMETERS

ABSTRACT

Objective techniques are being developed for interpreting grid-point analyses and prognoses produced by computerized dynamical models in terms of concomitant surface-weather conditions. This Technical Report describes the project and work accomplished on it since May 1963.

Multiple regression equations were derived to express statistical relationships between surface-weather variables and derived upper-air parameters representing pertinent physical processes taking place between the surface and the 500-mb level. These upper-air (predictor) parameters were derived from observed height and thickness values and the climatological statistics of these values.

The work presently being conducted and plans for future work are discussed. Improvement is being sought by the definition of better predictor parameters to represent orographic effects and by the incorporation of moisture (cloud amount) information now available from dynamical models. The equations will be tested on real-time upper-air prognoses and readied for use in an operational test by the Air Weather Service by September 1965.

REVIEW AND APPROVAL

Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

Robert L. Houghten
Robert L. Houghten
Lt. Colonel, USAF
Acting System Program Director

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SECTION I

INTRODUCTION

1. Purpose

This is an interim Technical Report on Project 3.0 of the 433L Meteorological Technique Development Program (Contract AF 19(628)-3437). Objective techniques are being developed to interpret grid-mesh analyses and prognoses produced by computerized dynamical models in terms of concomitant surface-weather conditions such as ceiling, visibility, etc. The techniques can be applied to analyses to diagnose current terminal weather conditions at locations for which no surface observations are available, and can be applied to prognoses to obtain predictions of surface-weather conditions at selected terminals. Previous work on this project (reported through May 1963 [2]) indicated the feasibility of deriving generalized statistical operators for diagnosing surface-weather conditions for concomitant upper-air parameters. The present report covers the period from October 1963 through December 1964.

2. Objectives

The earlier report [2] described results obtained with statistical regression-equation models whose predictor terms were restricted to parameters derivable from 500-, 700-, and 1000-mb height values, the long term climatology of these fields (i.e., mean values and standard deviations), and the three thickness layers defined by them. The equations, derived for the period October through April, employ predictors of varying complexity, intended to represent pertinent physical processes taking place between the surface and the 500-mb level (e.g., thickness and vorticity advection). Predictor parameters were chosen subjectively, primarily on the basis of meteorological knowledge and experience, but were constrained to forms which could be incorporated readily into a routine operational forecast system.

The work described in this report has had the following specific objectives:

(a) to expand the generalized regression-equation system described in [2] so that equations are available for all seasons of the year.

(b) to enhance the diagnostic capability of the equations by using additional predictors which could take into account (i) vertical motion due to orographic effects, (ii) "coastal effects" resulting from permanent moisture sources (such as oceans and lakes) which affect surface conditions at specified grid points, and (iii) general radiation effects definable from time-of-day and latitudinal considerations.

3. Scope

The surface-weather variables (predictands) considered here are ceiling, visibility, total cloud amount, precipitation, and IOC (integrated operating conditions, i.e., categories of combined ceiling-visibility conditions, such as below 1500 feet and 3 miles, etc.). Regression equations are being derived to express statistical relationships between the predictand variable and the derived (predictor) parameters, under the "perfect prog" concept, i.e., the value of a predictand variable at a grid point is inferred from concomitant values of predictor parameters observed at or computed for that point alone. Further, the equations are generalized in that a single regression equation is applicable at any point over an extensive geographical region. Generalization is accomplished in two ways: (i) by using predictor parameters based on anomalies from local climatic normals and (ii) by suppressing statistical relationships pertinent to specific points only or by devising generalized predictor parameters representative of such effects at many locations, such as, a "coastal effect" term.[1] The equations are derived from data for 16 widely scattered points over the eastern and central United States. The applicability of the equations to other areas was assessed by applying them to selected series of 200-grid-point synoptic maps over the entire United States and adjacent areas. In future work, the equations derived from U.S. data will be evaluated on maps of other areas of the hemisphere.

4. Data

The five-year (April 1955 through March 1960) upper-air data sample consisted of twice-daily hemispheric manually gridded synoptic analyses of 500-, 700-, and 1000-mb height available on magnetic tape. The surface data consisted of

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[1] For definition and derivation of the "coastal effect" term, see Appendix II, parameter XCLL.

twice-daily (00Z and 12Z) observations for the period April 1955 through December 1958 from 31 U.S. stations east of the Rocky Mountains. Each station was selected to be as near as possible to an upper-air (standard JNWP) grid point. Data from 16 stations were combined to derive the generalized equations. Data from the remaining 15 stations were reserved for testing the generalized equations. Figure 1 shows the location of the 31 surface stations.

Climatological statistics required for the computation of anomaly-based predictors were derived from the full 5-year upper-air data samples. A discussion of the procedure used was reported previously [2]. These climatological data were compiled on magnetic tapes, by months.

The computations of all derived predictor parameters were performed for each in the data sample before the statistical screening procedure was applied. Daily climatological statistics were obtained by interpolation between monthly values. Each case in the data sample consists of concomitant observations of 5 surface (predictand) variables and 81 predictor parameters at one specific station and its nearby grid point. All cases from the 16 stations (see Figure 1) were combined into one generalized data sample to derive the equations (one such sample was compiled for each season). Similarly, a generalized data sample (for each season) was compiled from the remaining 15 stations as an independent test sample.

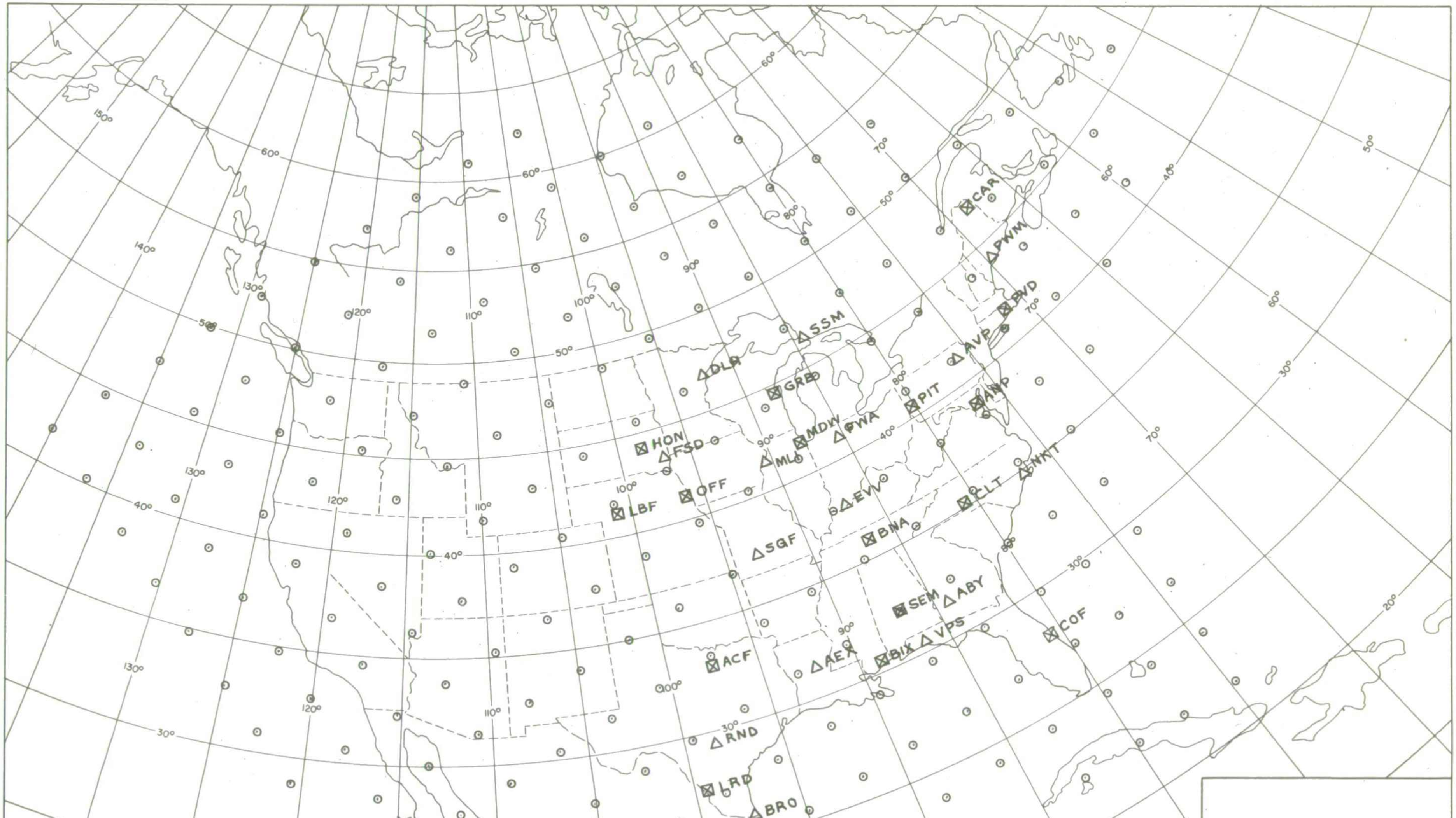

Figure 1. 31-surface-station network. Stations used in developmental sample for deriving equations indicated by ⊠, independent stations by Δ. Small circles ⊙ indicate 200-point grid network over which synoptic maps were computed.

SECTION II

SUMMARY

5. Background, Scope, Results

Other techniques are being developed for interpreting grid-point analyses and prognoses produced by computerized dynamical models in terms of concomitant surface-weather conditions. This Technical Report describes the project and work accomplished on it since May 1963.

Multiple regression equations were derived to express statistical relationships between surface-weather variables (such as ceiling and visibility) and derived upper-air parameters representing pertinent physical processes taking place between the surface and the 500-mb level (such as vorticity and thickness advection). These upper-air (predictor) parameters were derived from observed height and thickness values and the climatological statistics of these values.

The equations are generalized in that a single equation is applicable at any point over an extensive geographical region. The derived predictor parameters must be recomputed for each specific point at which an equation is to be solved. The generalized equations are discussed as statistical alternatives to dynamical models which may be operationally infeasible or as yet undeveloped.

Solution of a given equation for a specific point provides an ordered numerical index which represents the probability of occurrence of operationally-significant categories of the predictand (surface-weather) variable. Probability distributions for this purpose were obtained empirically by solving the equations for all cases of the developmental data sample. Solutions of the equation for many grid points over a synoptic map (using the independently derived predictor parameters for each grid point) yield directly to a diagnosis of the concomitant surface-weather patterns.

Equations were derived separately for 4 seasonal periods for each of 5 predictand variables: ceiling, visibility, total cloud amount, IOC (integrated operating conditions; i.e., combined categories of ceiling and visibility), and the occurrence of precipitation. The equations were derived on a sample of data combined from 16 surface stations over the central and eastern United States and tested on an

independent sample from 15 other stations in the same region. The results were compared with the results that would be obtained by applying climatological frequencies (probabilities) in all cases. Improvement over the climatological control technique ranged from 8 to 10 percent for ceiling, 7 to 14 percent for total cloud amount, 3 to 5 percent for visibility, 7 to 9 percent for IOC, and 12 to 16 percent for precipitation.

Two 3-day series of synoptic maps, presented, show the application of the equations over a 200-point grid network over the entire United States and adjacent areas. Subjective examination of these maps shows that the equations have ability to: (1) indicate appropriate changes in the surface-weather patterns corresponding with changes in the upper-air fields, (2) indicate, where appropriate, sharp gradients in the surface-weather index fields, and (3) locate the relative position of poor surface conditions with respect to surface pressure systems. The equations are shown to have obvious weaknesses, in particular with respect to poor surface conditions resulting from orographic effects over mountainous areas.

Improvement is being sought by the definition of better predictor parameters to represent orographic effects and by the incorporation of moisture (cloud amount) information now available from dynamical models. The equations will be tested on real-time upper-air prognoses and readied for use in an operational test by the Air Weather Service by September 1965.

SECTION III

APPROACH

6. Generalized Statistical Operators

The concept utilized in this study is to devise a single statistical operator (e.g., a regression equation or discriminant function) which can estimate a given surface-weather variable at any point over an extensive geographical region. Most applications of statistical methods to meteorological prediction have involved the analysis of historical data from a single geographic point or small area to obtain a prediction system applicable to that point or area only. The derivation of a generalized statistical operator, on the other hand, is approached through the analysis of a single data sample comprised of observations from numerous points over an extensive area. In the present work, for example, generalized regression equations for diagnosing surface-weather conditions as a function of other parameters have been derived from a combined data sample of observations from 16 stations widely scattered over the central and eastern United States (see Figure 1). The basic justification for assuming that generalized statistical operators are feasible lies in the concept that whereas the numerical values used to describe a given meteorological parameter may be strongly influenced by the climatic regime and geographical location in which it is observed, the same basic physical laws apply over all seasons and regions of the earth. The underlying approach in generalized statistical analysis is to examine historical data in such a way as to define generalized relationships which reflect the operation of basic physical processes common to all regions.

Dynamical prediction models are the foremost example of the use of generalized equations. Dynamical prediction equations are, in fact, direct representations of the operation of known physical laws and consist of mathematical expressions which simulate the processes in the free atmosphere. At present, however, there are no operationally-useful dynamical models available that describe and predict fields of critical surface-weather parameters such as ceiling, visibility, etc. The generalized statistical operator is conceived as a possible interim solution to this problem. The types of predictor parameters examined (for the statistical equations)

are similar to those which might be used in a true dynamical model; i.e., they represent processes which meteorological experience and insight suggest are pertinent to the problem and are capable of estimation from routinely-observed data. However, the choice of individual parameters for any given equation, and the weighting coefficients to be assigned to each, is determined by a statistical analysis of historical data, rather than by recourse to a preconceived physical model. The basic statistical nature of such equations suggests that their solutions be interpreted in probabilistic terms.

In the present work generalized statistical operators are being derived as part of a mixed dynamical-statistical system. Reliance is placed on the free-atmosphere dynamical model as a predictive mechanism. The statistical equations are intended for use primarily as a diagnostic tool; i.e., they are derived to represent concomitant surface-upper-air relationships which can be applied to dynamical prognostic charts and analyses.

The primary reasons for attempting generalized statistical operators in lieu of series of "point location" operators are practical reasons:

(a) In many areas of the world, historical data samples are unavailable or are too small to obtain usable results by statistical analyses.

(b) Where predictions or diagnoses for many locations are desired, the cost in time and resources may preclude the derivation of a multitude of specific-location operators.

The derivation of generalized statistical models for describing surface-weather upper-air relationships poses 3 basic problems:

(a) Predictor parameters must be devised which are operationally-useful measures of the pertinent physical processes. The usefulness of a generalized statistical operator depends entirely on how well the predictors represent such processes.

(b) The statistical models must have a built-in adaptability to varying climatic regimes, even though the geographical and temporal extent of such regimes seldom can be defined by simple mathematical functions of latitude, longitude, and time of year.

(c) The physical characteristics of the local area surrounding a given observing station or grid point (e.g., terrain, presence of coastlines, smoke sources, etc.) may give rise to significant statistical relationships which are valid only for that location. In an objective statistical analysis such as the so-called "screening" procedures, the existence of such singular relationships may preclude the selection of more generally useful predictor parameters.

In the present work the 3 problems have been attacked in the following manner:

(a) Generalized predictor parameters were derived from the original data prior to the statistical analyses. Predictors representing processes such as vorticity- and thickness-advection are in a form suitable for computation with routinely available data. Where more than one term is feasible to represent a given process, all terms were computed and the choice left up to the objective statistical screening process.

(b) The elimination of climatic bias is attempted through the use of anomalies, i.e., the deviations of height and thickness values from long-term climatological normals. The consideration of anomaly fields of this type as descriptive and predictive parameters is an established and long-used procedure, and is described extensively in professional literature, e.g., [3, 5]. In the present work the use of height- and thickness-anomaly fields has proved especially useful.

(c) The problem of geographic, or "local" effects has been approached in two ways:

(i) Generalized predictor parameters were derived to describe permanent local physical characteristics common to numerous locations. These include terms to represent local terrain and the resulting orographic effects, and to represent the effects of nearby ocean and lake shorelines.

(ii) The application of statistical screening procedures to generalized data samples (data from many stations) serves to suppress the selection of predictor parameters pertinent to restricted locations only.

7. Statistical Method Used

The Screening Multiple Linear Regression Technique [4] has been the basic statistical tool in this work. The technique is applied to a data sample consisting of observations of a predictand variable and a relatively large set of different predictor parameters. An efficient subset of predictors is selected objectively by computer and a multiple regression equation is derived to estimate the predictand variable as a linear function of the subset of selected predictors. The selection of predictors is such that each contributes significant information to the estimate over and above that contributed by all of the other predictors selected. The linearity of the equation resides only in the weighting coefficients assigned to the selected predictors. The predictors themselves, in particular those derived to represent physical processes such as vorticity advection, may be highly nonlinear.

8. Predictand and Predictor Parameters

Because of the discontinuities inherent in observations of surface-weather elements (e.g., unlimited ceilings and visibilities) the predictand data were subjected to a normalizing-transformation procedure aimed at making such variables more amenable to statistical regression analysis. For detailed discussion of this procedure see [2, Appendix A]. Precipitation data were available only in dichotomous form, i.e., occurrence or nonoccurrence at the time of observation. IOC (see section 4) was considered in 4 operational categories, i.e., (i) ceiling below 1500 feet and/or visibility less than 3 miles, (ii) ceiling between 1500 and 5000 feet and/or visibility between 3 and 5 miles, (iii) ceilings 5000 feet or more (but not unlimited) and/or visibility between 5 and 7 miles, and (iv) ceilings unlimited and visibility 7 miles or greater.

Numerous predictor parameters were derived to represent different atmospheric processes. These included representation of vorticity concepts, thermal advection and changes, vertical motion, and stability. All of the parameters were based on, and derivable from, observed 500-, 700-, and 1000-mb height values, climatological mean values and standard deviations for those three heights, and the three thickness layers defined by those heights.

Note that, thus far, no parameters based on direct observations of the moisture field or temperature patterns have been utilized (thermal processes were approached from thickness considerations). At the beginning of the project, data on these elements were not available in usable form. Further, although the techniques are being developed on concomitant surface and upper-air data, they are intended primarily for use with dynamical upper-air prognostic charts to infer future surface-weather conditions. At the start of the work, dynamical prognoses of upper-air moisture and temperature patterns were either unavailable or of questionable accuracy for the purposes of objective statistical analysis.

More recently, however, the development of dynamical moisture- and temperature-pattern prediction models has progressed so that the inclusion of such parameters appears feasible. Future plans for the present work are aimed at this improvement (see SECTION IV).

A major portion of the work reported here involved the definition and derivation of additional predictor parameters that can be compared routinely from information that would be available in an operational system. These parameters include:

(a) A parameter representing vertical motion caused by orographic effects. This parameter was computed by an expression similar to advection computations so as to be proportional to the strength of the geostrophic flow at 1000 mb across contours of terrain elevation.

(b) A parameter to reflect so-called "coastal effects"; i.e., the presence of a nearby ocean, lake, or other permanent moisture source. This parameter was also defined by an advection-type expression which was proportional to the component of the geostrophic flow at 1000 mb from the direction of the designated moisture source toward the grid point for which surface-weather conditions are to be estimated (see Appendix II, XCLL).

(c) A number of parameters to represent radiation or time-of-day conditions at each grid point. These expressions assume that the local (sun) time would be available in the operating system for all grid points, either in tables or computed from latitude-longitude considerations. The terms are relatively simple; they include the length of time between observation time and sunrise or sunset, the duration of daylight or nighttime, etc.

In addition to the data previously described, the parameters described above require this information in an operational system:

(a) Terrain elevation values (preferably smoothed) for each grid point where surface conditions are to be estimated.

(b) An array of "flag" integers to properly designate each grid point as a "coastal" or "non-coastal" point. The array of such integers would be permanent, at least through a given seasonal period.

(c) Appropriate values of latitude and longitude for use in converting observation (Z) time into the local (sun) time at each grid point. Latitude and longitude values could be established as permanent arrays in computer storage or computed when needed as functions of the grid point coordinates.

The computational forms of all predictor parameters selected for the regression equations are shown in Appendix II.

SECTION IV

THE EQUATIONS

9. Derivation

A total of 55[2] regression equations was derived to estimate the following surface-weather elements (predictands):

Ceiling

Visibility

Total Cloud Amount

Precipitation (occurrence or nonoccurrence)

IOC (4 categories; see section 8)

Equations were derived separately for each of 4 seasonal periods:

January through March

April through June

July through September, and

October through December

Three different equations were derived for each predictand element in each seasonal period. The first equation (Equation A) uses predictors selected from the original set of upper-air parameters only (see [2, Appendix IV]). For the second equation (Equation B) the set of possible predictors to be screened was expanded to include the orographic- and coastal-effect terms. For Equation C the set was further expanded to include the radiation, or time-of-day parameters.

The objectives in providing a choice of 3 equations for any given application were:

(a) To provide flexibility with respect to the computer facilities required for operational implementation. The complexity of the computer programs for applying the equations depends largely on the types of predictor parameters used. The application of the type A equations would be simplest. The type B and type C

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[2] The precipitation-index equations for the July through September season were found to be in error and must be rederived.

equations would require successively more involved computer programs and capabilities to derive the terrain, coastal, and time-of-day predictor (see section 8).

(b) To evaluate the contribution of the terrain, coastal and time-of-day parameters over and above that obtained with the original predictors.

(c) To provide a "backup" for areas where the type B and type C equations may be found unsuitable. For example, an equation containing terrain- and coastal-effect terms would be inefficient when used over open-ocean areas where such terms are not relevant.

All regression equations are listed in Appendix I. Definition of the symbols identifying the predictor parameters and the computational formulas for each are given in Appendix II.

A total of 81 possible predictors was screened for the equations. Of these, 55 were selected for use in one or more equations. The maximum number of predictors selected for any one equation was arbitrarily limited to 10. The smallest number of significant predictors chosen for any one equation was 5. The frequencies with which the different types of predictor parameters were selected for the type C equations are given in Table I.

Certain features of the manner of predictor selection are worthy of note:

(a) Most equations contain predictors representing distinctly different atmospheric processes. Further, in each equation, each such process is usually defined by only one (at most, two) predictor parameters. For example, in most type A equations for ceiling the predictors represent the following parameters:

vorticity field
vorticity advection
the thickness field
thermal (thickness) advection
the height change field
stability (spring and summer only)

(b) The predictors representing orographic and coastal effects added significant information to the estimation of all predictands in one or more seasons.

TABLE I
FREQUENCY OF SELECTION OF DIFFERENT TYPES OF PREDICTOR PARAMETERS IN THE TYPE C[3] EQUATIONS

Type of predictor[4]	Predictand Variable					
	Ceiling	Visibility	Total cloud amount	IOC (cig-vsb)	Precip-No precip	Total
Coastal-effect terms	6	8	4	6	4	28
Time-of-day, or radiation term	4	9	6	6	0	25
Space-mean vorticity fields	6	3	4	4	5	22
Advection of thickness anomalies	4	4	4	4	3	19
Advection of height anomalies	4	4	4	4	2	18
Terrain-effect term	4	2	4	4	3	17
Height change fields	3	4	4	4	1	16
Stability parameters	4	0	2	3	3	10
Thickness anomalies	1	2	2	1	1	7
Height anomalies	1	1	1	3	1	7
Height fields	1	1	1	1	3	7
Advection of thickness change	0	0	2	0	0	2
Advection of height change	0	0	0	0	1	1
Thickness field	0	0	1	0	0	1

[3] Three type C equations were available for precipitation, four for all others: see footnote 2.

[4] A list of the individual predictor terms is given in Appendix II.

(c) The time-of-day parameters added still more significant information to the estimation of all predictands except precipitation, and were selected most frequently in the equations for estimating visibility.

(d) Parameters representing vorticity advection were computed in two ways. In the first method, the relative vorticity field was defined by the derivation of observed heights from space mean height values. In the second method, the vorticity field was represented by the height anomaly field (see [5, p. 21]). The first term is a measure of the flow across space mean contours; the second term measures the flow across climatic normal contours. Without exception, when a vorticity advection predictor was selected for an equation the term based on the height anomaly field was chosen, suggesting that the latter form may be statistically more stable and operationally more useful. This result supports similar findings described in earlier work by Martin [5, p. 54].

10. Interpretation

A given equation solution is an estimate of the parameter by which observed categories of the predictand variable were represented in the generalized developmental data sample (e.g., normalizing transformation value, zero-one parameter, etc.; see section 8). This estimate ($\hat{Y}$) is a numerical index which can be interpreted in terms of the probability of occurrence of any given category of the predictand, at the point for which the equation was solved. A given value of $\hat{Y}$ consequently provides an estimation of the probability distribution over all predictand categories. A set of probability distributions to relate different values of $\hat{Y}$ with a given set of predictand categories can be derived empirically.

The index ($\hat{Y}$ values) can be analyzed directly on a synoptic map (see section 11) as a subjective aid in defining present and/or future areas of relatively "good" or "poor" surface conditions over the region to which the generalized equation is applied. The set of empirical probability distributions provides an objective means for interpreting the numerical indices (equation solutions) in terms of observable values (categories) of the predictand variable.

For the present equations (derived on U.S. data), probability distributions over selected sets of operationally-significant categories of the predictand variables

were obtained empirically in the following manner. The equation for a given predictand was solved for each case of the developmental data sample. The individual $\hat{Y}$ values were arranged in ascending order and grouped into a manageable number of ordered ranges of $\hat{Y}$ value. The predictand category observed for each individual $\hat{Y}$ value was determined and a contingency table prepared to show the number of times each predictand category was observed within each $\hat{Y}$ range. The relative frequency of a predictand category within a given $\hat{Y}$ range represents the empirical probability of occurrence of that category, given that the solution of the equation falls within that $\hat{Y}$ range. The spectrum of relative frequencies for that $\hat{Y}$ range consequently represents an empirical probability distribution over all predictand categories.

Contingency tables of this type were compiled for each predictand variable and season. For the purposes of this report, tables were derived for the type B equations (see section 9).[5] The stability of the empirical probability distributions derived from the developmental data was assessed by applying the equations to the reserved sample consisting of data for the 15 stations not included in the developmental sample. Contingency tables were again compiled as described above.

A Brier-Allen P score [1] was computed using (i) the empirical probability distributions of each table and (ii) the overall climatological frequencies of each table. In general, this score (on the contingency tables compiled from the independent data) was better (lower) during the spring and summer seasons, but showed the greatest improvement over climatology during the fall and winter seasons. The improvement over climatology for the 5 predictand variables was as follows:

Ceiling	: from 7% (Summer) to 10% (Winter)
Visibility	: from 3% (Winter) to 5% (Spring)
Total cloud amount	: from 7% (Summer) to 14% (Fall)
Precipitation	: from 12% (Spring) to 16% (Fall)
IOC	: from 4% (Summer) to 9% (Winter)

[5]At the time of this report, computer programs were not yet available to apply to type C equations (with time-of-day radiation parameters) on a grid-point network over wide areas. The type B equations could be so applied, and were applied on a series of synoptic maps (see section 10).

It must be remembered that the scores listed above represent results obtainable with analyses or "perfect prognoses" only. The results to be expected when real-time prognostic charts are used have not yet been determined (see SECTION V).

All of the contingency tables are presented in Appendix III. The ranges of $\hat{Y}$ value listed in the tables correspond to those for which contours were drawn on the synoptic-map series discussed in section 11.

The equations derived from U.S. data are being applied and their solutions (indices) analyzed over synoptic maps of different regions of the Northern Hemisphere, such as the entire United States and adjacent areas and areas of Europe and Western Asia (see section 11). It appears that maps of this type could provide useful tools objectively analyzing the large-scale, synoptic-map characteristics of surface-weather patterns associated with the upper-air circulation analyses and prognoses produced by computerized dynamical models.

The empirical probability distributions derived from the 16-station generalized sample appear to provide useful interpretations of index analyses in terms of observable predictand values (such as ceiling heights) throughout the areas encompassed by the 31 stations to which they have been applied, viz., the central and eastern United States. The statistical stability of the equations can be assessed by a comparison of the relative frequency distributions and Brier-Allen P scores obtained on the contingency tables for the independent 15-station sample with those computed on the 16-station developmental sample (see Appendix III). In previous work [2], generalized equations derived from a combined data sample from 10 stations were applied to 5 other stations: these results were then compared with results obtained by "single station" equations derived specifically for each of the 5 stations from its own data only. The comparison showed no consistent significant difference in the results.

The empirical probability distributions derived from the 31-station U.S. data samples might also be useful as "first estimates" for other regions, particularly regions for which historical data are sparse or unavailable. Nevertheless, better results could undoubtedly be obtained from additional relative-frequency contingency tables compiled for regions or specific locations of particular operational importance.

The form of such tables (i.e., the number and limits of predictand categories) could be chosen so as to satisfy best the operational requirements of the particular region or station. It is suggested that a valuable objective procedure might be devised for forecasting surface conditions at specific important terminals by compiling a scatter-diagram to relate computed index values from the generalized equations to concomitant values of the predictands at that station.

11. Application to Synoptic Maps

The type B equations for the January through March and July through September seasons have been applied to three years of daily (12Z) upper-air charts for February (1956—58) and August (1955—57). Indices for the 5 predictand variables were computed for each day over two 200-point grid networks, the first over the United States and adjacent areas (see Figure 1), the other over Europe, the Mediterranean, and western Asia. Two 3-day series of these maps over the U.S. grid network (14—16 February 1958 and 12—14 August 1955) are presented in this report. The series were selected as exhibiting prominent and well-defined surface-weather patterns which would provide a means for a subjective evaluation of the ability of the equations to indicate such patterns. The February series shows the progression of a well-defined low-pressure center from the Texas Panhandle across the Gulf Coast States and up the Atlantic coast to Long Island. A high-pressure cell intrudes southward into the Plains States, while a typical occluded frontal system moves in from the Pacific Ocean across the Northwestern States. In the August series, an elongated high-pressure cell over the central and north central United States moves rapidly eastward as a hurricane, located over Cape Hatteras on August 12, moves inland to become an extratropical low center over Lake Huron on August 14.

The maps for the February series are presented in Appendix IV; those for the August series, in Appendix V. The following maps are shown for each day of each series:

(a) Maps of the 500-mb height and surface-pressure pattern analyzed for values at grid points only. These two fields, in conjunction with the 700-mb height field and height- and thickness-climatological data (not shown) represent the basic

data from which derived predictor parameters were computed to solve the regression equations.

(b) Separate maps for each of the 5 predictand indices, analyzed for the values computed at grid points.[6]

(c) The observed surface-synoptic chart for that day reproduced from the Historical Daily Series [6].

Detailed discussion of each map is impractical within the scope of this report. Ceiling and visibility data are not reported directly on the observed surface chart, although indications of value can be inferred from the coded cloud heights and present weather symbols shown. Total cloud amount must be inferred from the shaded station circles. Nevertheless, the maps do permit a subjective evaluation of the information furnished by the index fields. The contours drawn for each index field can be interpreted through the appropriate probability distributions obtained from the contingency tables given in Appendix III.

The encouraging features described in the previous work [2] are again evident on the present maps:

(a) The equations show ability to relate changes in the upper-air pattern to corresponding changes in the indicated surface-weather patterns. This can be observed in the February series, for example, in the movement of the low-ceiling indications to correspond with the movement of the 500-mb trough and low-pressure center from Texas east and northeastward.

(b) There is apparent skill in locating the position of poor surface conditions relative to surface-pressure systems. On the maps for 14 February, for example, the indications for poorer surface-weather conditions, i.e., low ceilings and visibilities, (higher precipitation probabilities) are found on the eastern side of the low surface-pressure center over the Texas Panhandle.

(c) The equations have an apparent ability to define, within relatively short geographical distances, sharp distinctions between areas of poor and good surface

---

[6] Maps of the precipitation index for the August series are omitted. See footnote 2.

conditions. This is particularly evident on the maps for August 12 in the sharp gradient of the ceiling index in the direction from which the hurricane is moving. This gradient corresponds well with the conditions shown on the observed surface map, and contrasts sharply with the relatively flat ceiling-index gradient extending to the northeast, or leading direction of the storm.

The incorporation into the equations of orographic- and coastal-effect terms has improved the results, in particular along the west coast and eastern slopes of the Rocky Mountains. The type A equations applied in the previous report [2] did not provide indications of low ceilings, for example, along the west coast to correspond with conditions such as were observed there on 14 February. Nor could they define, as does the ceiling-index map for 15 February (derived with the type B equation), indications of orographic low-cloud conditions over western Kansas and Colorado.

The maps show the equations to have obvious weaknesses, in particular when they are applied over mountainous regions. On the maps for 14 February, for example, a low precipitation index (low probability of occurrence) over western Montana coincides with an extensive area of continuous snowfall. Examination of the individual predictor parameters in this case showed that the estimation was strongly influenced by the orographic-effect term. In this instance, this parameter indicated a spurious downslope flow resulting from unrepresentative elevation values assigned to the nearby grid points. The plans for future work to improve this and other observed weaknesses are discussed in the following section.

SECTION V

FUTURE WORK

The work in this project presently being conducted or planned for the immediate future is aimed at preparing a regression-equation system which can be applied on an operational-test basis at the Global Weather Central (GWC). The plans provide for the system to be complete and ready for testing by September 1965. The specific objectives of the work to be accomplished by that date are:

(a) To improve the present equations (or derive new equations) to utilize information available from analyses and prognoses of upper-air moisture patterns provided by the dynamical (backward-trajectory) cloud model now in operation at the Global Weather Central. A simple approach, again using the "perfect prognoses" concept, is being tried first. New equations for ceiling, visibility, precipitation and IOC are being derived under the assumption that the total cloud amount observed at each grid point is known or has been accurately forecast. In application, this predictor would be obtained from cloud analyses (in some regions, perhaps, based on satellite observations) or from the dynamical cloud prognoses.

(b) To refine the terrain-elevation parameters or to re-derive the orographic-effect parameters to eliminate the inconsistencies observed when the present equations were applied over mountainous areas (see section 11). A smoothed terrain-elevation field used for the GWC dynamical models is being examined as a possible improvement. In addition, the terrain-effect parameter is being re-defined to utilize, for the advection-type computations, a measure of the geostrophic flow at the elevation of the central grid point, rather than a measure based on 1000-mb height values exclusively. These changes in this parameter can be expected to require re-derivation of all equations in which it is used.

(c) To transform the present equations, or to derive new equations which can make use of surface predictand (or predictor) data available for times preceding the valid time of the dynamical prognoses being used to solve the equations. One way in which the present equations can be transformed for this purpose is as follows:

Consider any one of the present equations (assume, for simplicity, that it uses only 1 predictor). It was derived in the form

$$\hat{Y}_0 = a + bX_0 \tag{IV-1}$$

where X_0 is the predictor value, $\hat{Y}_0$ the index estimate for the same time (time 0) and a and b are weighting coefficients. The equations are applied to dynamical prognostic charts in the following sense:

$$\hat{Y}_T = a + b\hat{X}_T \tag{IV-2}$$

where $\hat{X}_T$ is the <u>prognostic</u> value of the predictor at some time T (e.g., 24 hours) in the future which represents the valid time of the prognostic chart.

Assume that in a given application we have available observed or analyzed values of Y_0 and X_0, as well as $\hat{X}_T$. From Equation (IV-1) we also have $\hat{Y}_0$. Then $Y_0 - \hat{Y}_0$ represents the <u>diagnostic error</u> incurred by Equation (IV-1) at the given grid point at initial time 0. If we assume that this diagnostic error persists in its entirety throughout the forecast period from 0 to T, we have a revised estimate of $\hat{Y}$ for time T, vis. $\hat{\hat{Y}}_T$, such that

$$\hat{\hat{Y}}_T = \hat{Y}_T + (Y_0 - \hat{Y}_0) \tag{IV-3}$$

Substituting Equations (IV-1) and (IV-2) we have

$$\hat{\hat{Y}} = a + b\hat{X}_T + Y_0 - a - bX_0$$

$$\hat{\hat{Y}}_T = Y_0 + b(\hat{X}_T - X_0) \tag{IV-4}$$

or

$$\hat{\hat{Y}}_T - Y_0 = b(\hat{X}_T - X_0)$$

Equation (IV-4) represents a forecast of the <u>change</u> in the index from its observed value at time 0, based upon the <u>change</u> forecasted for the predictor X for that period by the dynamical model. The treatment of additional predictors would be the same. Under the assumption that the initial diagnostic error persists, no re-derivation of equations would be required, i.e., the value of b is the same in Eqs. (IV-1) and (IV-4). The validity of the basic assumption is being assessed. The present equations are applied in the revised form to the data samples

previously used, using values of Y_0 and X_0 observed 12, 24, and 36 hours previous to the time of the current data. The basic assumption will obviously be questionable for that portion of the diagnostic error $(Y_0 - \hat{Y}_0)$ due to dynamical effects such as poor predictor definition or the incorrect movement of synoptic features (e.g., troughs and ridges) during the forecast period. Nevertheless, it may prove valid at grid points where the initial diagnostic error is largely a result of persistent local effects (e.g., terrain characteristics) not considered by the equations. It is worth noting that Eq. (IV-4) could be used in a more general sense:

$$\hat{\hat{Y}}_T = Y_t + b(\hat{X}_T - \hat{X}_t) \qquad \text{(IV-5)}$$

in which the subscript t refers to any given time (e.g., hour) during the forecast period between 0 and T. Equation (IV-5) would provide a means for utilizing asynoptic observations of Y_t and/or X_t to adjust the original estimate $\hat{\hat{Y}}_T$ to later-observed data. Values of $\hat{X}_t$ could presumably be obtained, if necessary, from hourly iterations of the dynamical prognostic model.

(d) To evaluate the usefulness of the equations when applied to real-time prognostic data. In their present form, the equations are an optimized estimate of <u>concomitant</u> relationships between predictand and predictor parameters. As such, they are appropriate means for diagnosing surface-weather conditions over areas for which upper-air analyses are at hand but surface observations are unavailable. Their suitability for application to dynamical <u>prognostic</u> charts, however, can be assessed only on a real-time basis, i.e., by actually applying them to prognostic charts and analyzing the results from both objective and subjective standpoints. The complexity of the parameters utilized in the dynamical model and the predictors used in the regression equations would make a purely analytical analysis of potential errors impractical. One obvious source of error would be the "flattening" or "smoothing" of wave patterns evidenced on dynamical prognoses for longer periods, e.g., from 48—96 hours. Height anomaly fields, for example, could be expected to be less well defined on such maps. Separate equations could be derived, of course, for various forecast periods from real prognostic data. Such equations would, however, be "locked in" on the particular dynamical model which produced the prognoses, and might require re-derivation to accommodate

changes. A possible simpler solution can be suggested. In lieu of separate equations for different forecast periods, separate contingency tables (i.e., probability distributions—see Appendix III) could be compiled for each pertinent forecast period, so that the initial set of equations could be applied and correctly interpreted over all periods. In the event of changes in or revisions to a given dynamical model, the compilation of new tables for longer forecast periods would be a clerical task which could commence immediately upon initiation of the changed model.

A test of the present equations on a sample of real-time prognostic data will be conducted before completion of this project. Magnetic tapes containing dynamical prognostic data for an extended period have been obtained from the Global Weather Central for the purpose. Nevertheless, it appears likely that for practical (data-processing) reasons, a comprehensive test of this nature must await the implementation of the equations on an operational-test basis.

APPENDIX I

EQUATIONS

Specification Equations - Season I (Jan - Mar)[7]

Predictor Set A: Utilizing only predictors derived from 1000-mb, 700-mb, and 500-mb Heights and Climatology.

CIG (EQ A)

$$= -\ 0.036662 - 0.00029588\ (XA5) + 0.00034378\ (XATS5) + 0.0083152\ (DH7) - 0.014255\ (AT75) - 0.044286\ (V5)$$

VIS (EQ A)

$$= -\ .0032182 - 0.00031182\ (XA5) + 0.00033712\ (XATS5) + 0.0071536\ (DH7) - 0.0047047\ (A5) - 0.025755\ (V5)$$

TCA (EQ A)

$$= -\ 0.037024 + 0.00035089\ (XA5) - 0.00034799\ (XATS5) - 0.0071313\ (DH7) + 0.19419\ (ST75) + 0.028334\ (V5)$$

PCP (EQ A)

$$= 1.8598 - 0.00033048\ (XV5T) + 0.01814\ (V7) - 0.001737\ (H7) + 0.0017149\ (A5) - 0.0028765\ (DH7) - 0.0027809\ (XSTS7)$$

IOC (EQ A)

$$= 3.8579 - 0.00038344\ (XA5) + 0.00045339\ (XATS5) + 0.010211\ (DH7) - 0.01923\ (AT75) - 0.056292\ (V5)$$

---

[7]Notation in parentheses beside numerical coefficients designates selected predictor. Predictor notation is identified in Appendix II.

Specification Equations - Season I (Jan - Mar)[7]

Predictor Set B: Utilizing predictors derived from 1000-mb, 700-mb, and 500-mb Heights and Climatology plus Coastal and Terrain Terms.

CIG (EQ B)

$$
\begin{aligned}
= -\,0.042053 &- 0.00021316\ (\text{XA5}) - 0.000070704\ (\text{XEL}) \\
&- 0.027964\ (\text{VS}) + 0.00025944\ (\text{XATS5}) \\
&+ 0.0070219\ (\text{DH7}) - 0.013230\ (\text{AT75}) \\
&- 0.044080\ (\text{V5}) + 0.0053553\ (\text{XCLL})
\end{aligned}
$$

VIS (EQ B)

$$
\begin{aligned}
= 0.13937 &- 0.00025122\ (\text{XA5}) + 0.010517\ (\text{XCLL}) \\
&+ 0.00026933\ (\text{XATS5}) - 0.22763\ (\text{CID}) \\
&+ 0.0046850\ (\text{DH7}) - 0.12957\ (\text{STS5}) \\
&- 0.023709\ (\text{V5})
\end{aligned}
$$

TCA (EQ B)

$$
\begin{aligned}
= -\,0.047930 &+ 0.00029149\ (\text{XA5}) + 0.000063576\ (\text{XEL}) \\
&- 0.00035005\ (\text{XATS5}) - 0.0064892\ (\text{DH7}) \\
&+ 0.17991\ (\text{ST75}) + 0.034030\ (\text{V5}) \\
&+ 0.000091544\ (\text{XDTS5}) - 0.0043348\ (\text{XCLL})
\end{aligned}
$$

PCP (EQ B)

$$
\begin{aligned}
= 2.2995 &+ 0.000026005\ (\text{XEL}) - 0.0021777\ (\text{H7}) \\
&- 0.00026611\ (\text{XV5T}) - 0.0031202\ (\text{XCLL}) \\
&+ 0.010628\ (\text{VS}) + 0.0035409\ (\text{AT75}) \\
&+ 0.013076\ (\text{V5})
\end{aligned}
$$

IOC (EQ B)

$$
\begin{aligned}
= 3.8493 &- 0.00027794\ (\text{XA5}) - 0.000086709\ (\text{XEL}) \\
&- 0.036621\ (\text{VS}) + 0.00034546\ (\text{XATS5}) \\
&+ 0.0085045\ (\text{DH7}) - 0.017856\ (\text{AT75}) \\
&- 0.055900\ (\text{V5}) + 0.0071629\ (\text{XCLL})
\end{aligned}
$$

---

[7] Notation in parentheses beside numerical coefficients designates selected predictor. Predictor notation is identified in Appendix II.

Specification Equations - Season I (Jan - Mar)[7]

<u>Predictor Set C</u>: Utilizing predictors derived from 1000-mb, 700-mb, and 500-mb Heights, Climatology, Coastal and Terrain Terms plus Radiation Terms.

<u>CIG (EQ C)</u>

$$\begin{aligned}
= -\,0.27674 &- 0.00021495\ (\text{XA5}) - 0.000071179\ (\text{XEL}) \\
&- 0.027643\ (\text{VS}) + 0.00026123\ (\text{XATS5}) \\
&+ 0.0069794\ (\text{DH7}) - 0.013512\ (\text{AT75}) \\
&- 0.044695\ (\text{V5}) + 0.016548\ (\text{STM}) \\
&+ 0.0052102\ (\text{XCLL})
\end{aligned}$$

<u>VIS (EQ C)</u>

$$\begin{aligned}
= -\,0.13930 &- 0.00023494\ (\text{XA5}) + 0.0089670\ (\text{XCLL}) \\
&+ 0.00025385\ (\text{XATS5}) - 0.23746\ (\text{CID}) \\
&+ 0.028747\ (\text{STM}) + 0.0046824\ (\text{DH7}) \\
&- 0.14583\ (\text{STS5}) - 0.025074\ (\text{V5}) \\
&+ 0.0055241\ (\text{THEAT}) - 0.000028983\ (\text{XEL})
\end{aligned}$$

<u>TCA (EQ C)</u>

$$\begin{aligned}
= 0.25013 &+ 0.00029122\ (\text{XA5}) + 0.000063980\ (\text{XEL}) \\
&- 0.00035558\ (\text{XATS5}) - 0.0065461\ (\text{DH7}) \\
&+ 0.17886\ (\text{ST75}) - 0.018045\ (\text{STM}) \\
&+ 0.034157\ (\text{V5}) + 0.000094015\ (\text{XDTS5}) \\
&- 0.0041988\ (\text{XCLL}) - 0.014229\ (\text{TAST})
\end{aligned}$$

<u>PCP (EQ C)</u>

No change from EQ B.

<u>IOC (EQ C)</u>

$$\begin{aligned}
= 4.6438 &- 0.00027604\ (\text{XA5}) - 0.000089356\ (\text{XEL}) \\
&- 0.037390\ (\text{VS}) + 0.00033508\ (\text{XATS5}) \\
&+ 0.0082448\ (\text{DH7}) - 0.018325\ (\text{AT75}) \\
&+ 0.025942\ (\text{STM}) - 0.056605\ (\text{V5}) \\
&+ 0.0072725\ (\text{XCLL}) - 0.17151\ (\text{SR})
\end{aligned}$$

---

[7] Notation in parentheses beside numerical coefficients designates selected predictor. Predictor notation is identified in Appendix II.

Specification Equations - Season II (Apr - Jun)[7]

Predictor Set A: Utilizing only predictors derived from 1000-mb, 700-mb, and 500-mb Heights and Climatology.

CIG (EQ A)

$$
\begin{aligned}
= -\,0.671 &- 0.0042739\,(XS5) - 0.049184\,(V7) \\
&+ 0.00088101\,(XATS7) + 0.46814\,(STVT) \\
&+ 0.0065718\,(DH5) - 0.00064679\,(XA7)
\end{aligned}
$$

VIS (EQ A)

$$
\begin{aligned}
= -\,0.026439 &- 0.00030830\,(XA7) + 0.00074589\,(XATS7) \\
&+ 0.0065696\,(DH7) - 0.0011623\,(XAS) \\
&- 0.00018153\,(XA5) + 0.13233\,(STVT)
\end{aligned}
$$

TCA (EQ A)

$$
\begin{aligned}
= 0.65645 &+ 0.00059721\,(XA5) - 0.00070210\,(XATS5) \\
&+ 0.029627\,(V7) - 0.43782\,(STVT) \\
&- 0.0069458\,(DH5) + 0.00017726\,(XDTS5)
\end{aligned}
$$

PCP (EQ A)

$$
\begin{aligned}
= 1.3404 &+ 0.018426\,(V7) + 0.000029095\,(XDH5) \\
&- 0.00043517\,(XV7T) - 0.0012251\,(H7) \\
&+ 0.00045185\,(XAS) - 0.000086141\,(XSTBA)
\end{aligned}
$$

IOC (EQ A)

$$
\begin{aligned}
= 2.7936 &- 0.00043406\,(XA5) + 0.77237\,(STVT) \\
&+ 0.0010234\,(XATS7) + 0.0082896\,(DH5) \\
&- 0.049855\,(VS) - 0.0017291\,(XAS)
\end{aligned}
$$

---

[7] Notation in parentheses beside numerical coefficients designates selected predictor. Predictor notation is identified in Appendix II.

Specification Equations - Season II (Apr - Jun) [7]

<u>Predictor Set B</u>: Utilizing predictors derived from 1000-mb, 700-mb, and 500-mb Heights and Climatology plus Coastal and Terrain Terms.

<u>CIG (EQ B)</u>

$$
\begin{aligned}
= 0.56055 &- 0.0037313\ (\text{XS5}) - 0.032143\ (\text{V7}) \\
&- 0.000057752\ (\text{XEL}) + 0.00063710\ (\text{XATS7}) \\
&+ 0.44411\ (\text{STVT}) - 0.037991\ (\text{VS}) \\
&+ 0.016815\ (\text{XCLL}) - 0.017040\ (\text{XCLN}) \\
&+ 0.0049610\ (\text{DH5}) - 0.00050894\ (\text{XA7})
\end{aligned}
$$

<u>VIS (EQ B)</u>

$$
\begin{aligned}
= 0.24634 &- 0.35623\ (\text{CID}) + 0.011532\ (\text{XCLL}) \\
&- 0.00057291\ (\text{XA7}) + 0.00058206\ (\text{XATS7}) \\
&+ 0.0048199\ (\text{DH7}) - 0.031312\ (\text{VS}) \\
&+ 0.14370\ (\text{STVT})
\end{aligned}
$$

<u>TCA (EQ B)</u>

$$
\begin{aligned}
= 1.1688 &+ 0.00054384\ (\text{XA5}) - 0.00057325\ (\text{XATS5}) \\
&+ 0.0072458\ (\text{V7}) + 0.000057912\ (\text{XEL}) \\
&- 0.72506\ (\text{STVT}) - 0.0058727\ (\text{DH5}) \\
&+ 0.037829\ (\text{VS}) + 0.00013168\ (\text{XDTS5}) \\
&- 0.12644\ (\text{XCLD}) + 0.10078\ (\text{STBS})
\end{aligned}
$$

<u>PCP (EQ B)</u>

$$
\begin{aligned}
= 1.1614 &+ 0.015487\ (\text{V7}) + 0.000017775\ (\text{XDH5}) \\
&- 0.0057538\ (\text{XCLL}) + 0.0067115\ (\text{XCLN}) \\
&- 0.00010321\ (\text{XV7T}) - 0.0010696\ (\text{H7}) \\
&+ 0.000011389\ (\text{XEL}) + 0.000093397\ (\text{XA5}) \\
&- 0.00011635\ (\text{XATS5}) - 0.00089126\ (\text{DH5})
\end{aligned}
$$

<u>IOC (EQ B)</u>

$$
\begin{aligned}
= 3.0361 &- 0.00015628\ (\text{XA5}) + 0.67465\ (\text{STVT}) \\
&+ 0.00084240\ (\text{XATS7}) + 0.0056702\ (\text{DH5}) \\
&- 0.000067687\ (\text{XEL}) - 0.056055\ (\text{VS}) \\
&+ 0.020889\ (\text{XCLL}) - 0.020162\ (\text{XCLN}) \\
&- 0.026646\ (\text{V5}) - 0.00065771\ (\text{XA7})
\end{aligned}
$$

---

[7] Notation in parentheses beside numerical coefficients designates selected predictor. Predictor notation is identified in Appendix II.

Specification Equations - Season II (Apr - Jun)[7]

Predictor Set C: Utilizing predictors derived from 1000-mb, 700-mb, and 500-mb Heights, Climatology, Coastal and Terrain Terms plus Radiation Terms.

CIG (EQ C)

$$
\begin{aligned}
= -\,0.33751 &- 0.0087223\ (\text{XS5}) - 0.040620\ (\text{V7}) \\
&- 0.000059424\ (\text{XEL}) + 0.00050161\ (\text{XATS7}) \\
&+ 0.35985\ (\text{STVT}) - 0.043265\ (\text{VS}) \\
&+ 0.019016\ (\text{XCLL}) - 0.018077\ (\text{XCLN}) \\
&- 0.038529\ (\text{HTGV})
\end{aligned}
$$

VIS (EQ C)

$$
\begin{aligned}
= 0.20117 &- 0.36784\ (\text{CID}) + 0.011172\ (\text{XCLL}) \\
&- 0.00057230\ (\text{XA7}) + 0.00060590\ (\text{XATS7}) \\
&+ 0.0086705\ (\text{THEAT}) + 0.0053138\ (\text{DH7}) \\
&+ 0.048118\ (\text{RADN}) - 0.026791\ (\text{VS})
\end{aligned}
$$

TCA (EQ C)

$$
\begin{aligned}
= 4.0806 &+ 0.00057416\ (\text{XA5}) - 0.00059412\ (\text{XATS5}) \\
&+ 0.030617\ (\text{V7}) + 0.000060034\ (\text{XEL}) \\
&+ 0.23121\ (\text{TOD}) - 0.0075543\ (\text{DH7}) \\
&- 0.0044024\ (\text{TS7}) + 0.00015211\ (\text{XDTS5}) \\
&- 0.10552\ (\text{XCLD})
\end{aligned}
$$

PCP (EQ C)

No change from EQ B.

IOC (EQ C)

$$
\begin{aligned}
= 3.0278 &- 0.00037024\ (\text{XA5}) + 0.60124\ (\text{STVT}) \\
&+ 0.00083898\ (\text{XATS7}) + 0.0054088\ (\text{DH5}) \\
&- 0.000068391\ (\text{XEL}) - 0.048124\ (\text{VS}) \\
&+ 0.0060027\ (\text{THEAT}) + 0.022435\ (\text{XCLL}) \\
&- 0.020476\ (\text{XCLN}) + 0.085769\ (\text{SS})
\end{aligned}
$$

---

[7] Notation in parentheses beside numerical coefficients designates selected predictor. Predictor notation is identified in Appendix II.

Specification Equations - Season III (Jul - Sep)[7]

Predictor Set A: Utilizing only predictors derived from 1000-mb, 700-mb, and 500-mb Heights and Climatology.

CIG (EQ A)

$$\begin{aligned} = -0.92106 &- 0.0079627\ (XS5) + 0.67919\ (STVT) \\ &- 0.036441\ (VS) + 0.0010976\ (XV7T) \\ &+ 0.010391\ (DH5) + 0.00074017\ (XATS7) \end{aligned}$$

VIS (EQ A)

$$\begin{aligned} = 27.445 &- 0.00048849\ (XA7) + 2.9202\ (STVT) \\ &+ 0.0085821\ (DHS) - 0.031177\ (H7) \\ &- 0.075517\ (STBA) + 0.028150\ (A7) \end{aligned}$$

TCA (EQ A)

$$\begin{aligned} = 0.74302 &+ 0.0097542\ (XS5) - 0.0015206\ (XV7T) \\ &- 0.57700\ (STVT) - 0.011089\ (DH5) \\ &- 0.00095481\ (XATS7) + 0.037742\ (VS) \end{aligned}$$

IOC (EQ A)

$$\begin{aligned} = 1.7829 &- 0.0094278\ (XS5) + 1.4079\ (STVT) \\ &- 0.032687\ (VS) + 0.0012922\ (XV7T) \\ &+ 0.011394\ (DH5) + 0.00092896\ (XATS7) \\ &- 0.021232\ (STBA) \end{aligned}$$

---

[7] Notation in parentheses beside numerical coefficients designates selected predictor. Predictor notation is identified in Appendix II.

Specification Equations - Season III (Jul - Sep)[7]

Predictor Set B: Utilizing predictors derived from 1000-mb, 700-mb, and 500-mb Heights and Climatology plus Coastal and Terrain Terms.

CIG (EQ B)

$$
\begin{array}{llllll}
= -1.6395 & -\ 0.0074438 & (XS5) & +\ 1.0836 & (STVT) \\
 & -\ 0.039847 & (VS) & -\ 0.000048402 & (XEL) \\
 & +\ 0.0010225 & (XV7T) & +\ 0.0082219 & (DH5) \\
 & +\ 0.00061782 & (XATS7) & -\ 0.017654 & (STBA) \\
 & +\ 0.0075814 & (XCLL) & -\ 0.026531 & (V5)
\end{array}
$$

VIS (EQ B)

$$
\begin{array}{llllll}
= 11.105 & -\ 0.36329 & (CID) & -\ 0.00071604 & (XA7) \\
 & +\ 0.00094149 & (XATS7) & +\ 0.0075152 & (DH7) \\
 & -\ 0.035615 & (HS) & +\ 0.028535 & (AS) \\
 & -\ 0.010322 & (T75) & -\ 0.0010535 & (EL) \\
 & +\ 0.079610 & (S5) & -\ 0.00038399 & (XDTS7)
\end{array}
$$

TCA (EQ B)

$$
\begin{array}{llllll}
= 0.53153 & +\ 0.0091105 & (XS5) & -\ 0.0013463 & (XV7T) \\
 & -\ 0.52426 & (STVT) & -\ 0.010440 & (DH5) \\
 & -\ 0.0011200 & (XATS7) & +\ 0.000053764 & (XEL) \\
 & +\ 0.046827 & (VS) & +\ 0.22987 & (CID) \\
 & -\ 0.13952 & (XCLD) & +\ 0.00035315 & (XDTS7)
\end{array}
$$

IOC (EQ B)

$$
\begin{array}{llllll}
= 1.9811 & -\ 0.012624 & (XS5) & +\ 1.3584 & (STVT) \\
 & -\ 0.045441 & (VS) & +\ 0.010503 & (XCLL) \\
 & -\ 0.021578 & (STBA) & +\ 0.011597 & (DH5) \\
 & +\ 0.00085730 & (XATS7) & -\ 0.15947 & (CID) \\
 & +\ 0.0045204 & (XST75) & -\ 0.000044505 & (XEL)
\end{array}
$$

---

[7] Notation in parentheses beside numerical coefficients designates selected predictor. Predictor notation is identified in Appendix II.

Specification Equations - Season III (Jul - Sep)[7]

Predictor Set C: Utilizing predictors derived from 1000-mb, 700-mb, and 500-mb Heights, Climatology, Coastal and Terrain Terms plus Radiation Terms.

CIG (EQ C)

$$
\begin{aligned}
= -1.6242 &- 0.0072761\,(\mathrm{XS5}) + 1.1326\,(\mathrm{STVT}) \\
&- 0.041836\,(\mathrm{VS}) - 0.000054845\,(\mathrm{XEL}) \\
&+ 0.00088825\,(\mathrm{XV7T}) + 0.010035\,(\mathrm{DH5}) \\
&+ 0.00067114\,(\mathrm{XATS7}) - 0.015695\,(\mathrm{TBST}) \\
&- 0.020689\,(\mathrm{STBA}) + 0.0075324\,(\mathrm{XCLL})
\end{aligned}
$$

VIS (EQ C)

$$
\begin{aligned}
= 1.8203 &- 0.31750\,(\mathrm{CID}) - 0.051840\,(\mathrm{TBST}) \\
&+ 0.10274\,(\mathrm{RADN}) - 0.00052811\,(\mathrm{XA7}) \\
&+ 0.00065035\,(\mathrm{XATS7}) + 0.0083115\,(\mathrm{DH7}) \\
&+ 0.0075244\,(\mathrm{XCLL}) - 0.033964\,(\mathrm{ATS5}) \\
&- 0.030350\,(\mathrm{HS}) + 0.029484\,(\mathrm{A5})
\end{aligned}
$$

TCA (EQ C)

$$
\begin{aligned}
= 1.0834 &+ 0.0093423\,(\mathrm{XS5}) - 0.0014892\,(\mathrm{XV7T}) \\
&- 0.49915\,(\mathrm{STVT}) - 0.010506\,(\mathrm{DH5}) \\
&- 0.00089385\,(\mathrm{XATS7}) + 0.19626\,(\mathrm{TCD}) \\
&+ 0.000068788\,(\mathrm{XEL}) + 0.046942\,(\mathrm{VS}) \\
&+ 0.17601\,(\mathrm{CID}) - 0.14144\,(\mathrm{STM})
\end{aligned}
$$

IOC (EQ C)

$$
\begin{aligned}
= 2.3468 &- 0.0098031\,(\mathrm{XS5}) + 1.7786\,(\mathrm{STVT}) \\
&- 0.035453\,(\mathrm{TBST}) - 0.041010\,(\mathrm{STBA}) \\
&+ 0.013706\,(\mathrm{XCLL}) + 0.094354\,(\mathrm{SS}) \\
&+ 0.0010338\,(\mathrm{XATS7}) + 0.0099428\,(\mathrm{DH5}) \\
&- 0.000058051\,(\mathrm{XEL}) - 0.074030\,(\mathrm{DURD})
\end{aligned}
$$

---

[7] Notation in parentheses beside numerical coefficients designates selected predictor. Predictor notation is identified in Appendix II.

Specification Equations - Season IV (Oct - Dec)[7]

Predictor Set A: Utilizing only predictors derived from 1000-mb, 700-mb, and 500-mb Heights and Climatology.

CIG (EQ A)

$$
\begin{aligned}
= - 4.0349 &- 0.0093836\ (\text{XS5}) &&- 0.055221\ (\text{V7}) \\
&+ 0.0089440\ (\text{XSTS5}) &&+ 0.0070299\ (\text{DH7}) \\
&- 0.0048697\ (\text{A5}) &&+ 0.0022319\ (\text{H5})
\end{aligned}
$$

VIS (EQ A)

$$
\begin{aligned}
= 2.5237 &- 0.00040858\ (\text{XA7}) &&+ 0.00037646\ (\text{XATS7}) \\
&+ 0.0056249\ (\text{DH7}) &&- 0.0023697\ (\text{H7}) \\
&+ 0.00033404\ (\text{XV5T}) &&- 0.018470\ (\text{V7})
\end{aligned}
$$

TCA (EQ A)

$$
\begin{aligned}
= 6.0394 &+ 0.0099060\ (\text{XS5}) &&- 0.0062230\ (\text{H7}) \\
&- 0.00028338\ (\text{XATS5}) &&- 0.0082682\ (\text{DH7}) \\
&+ 0.0093479\ (\text{A7}) &&+ 0.042096\ (\text{V7}) \\
&+ 0.000056149\ (\text{XDH5})
\end{aligned}
$$

PCP (EQ A)

$$
\begin{aligned}
= 1.5044 &+ 0.012940\ (\text{V7}) &&- 0.00013871\ (\text{XV5T}) \\
&- 0.0013941\ (\text{H7}) &&+ 0.00018445\ (\text{XA7}) \\
&- 0.00016112\ (\text{XATS7}) &&- 0.00037877\ (\text{XAS}) \\
&- 0.0011644\ (\text{DH5}) &&+ 0.0014433\ (\text{AS})
\end{aligned}
$$

IOC (EQ A)

$$
\begin{aligned}
= - 0.37232 &- 0.00034889\ (\text{XA5}) &&- 0.064971\ (\text{V7}) \\
&+ 0.00038687\ (\text{XATS5}) &&+ 0.0067859\ (\text{DH5}) \\
&- 0.0068368\ (\text{A5}) &&+ 0.0043995\ (\text{H7})
\end{aligned}
$$

[7] Notation in parentheses beside numerical coefficients designates selected predictor. Predictor notation is identified in Appendix II.

Specification Equations - Season IV (Oct - Dec)[7]

<u>Predictor Set B</u>: Utilizing predictors derived from 1000-mb, 700-mb, and 500-mb Heights and Climatology plus Coastal and Terrain Terms.

<u>CIG (EQ B)</u>

$$
\begin{aligned}
= -6.3925 &- 0.0066930\ (\mathrm{XS5}) - 0.000077249\ (\mathrm{XEL}) \\
&- 0.034411\ (\mathrm{VS}) + 0.0065636\ (\mathrm{H7}) \\
&+ 0.0094689\ (\mathrm{XCLL}) - 0.0058720\ (\mathrm{A5}) \\
&+ 0.0067977\ (\mathrm{DH7}) + 0.0067698\ (\mathrm{XSTS5}) \\
&- 0.026928\ (\mathrm{V5}) - 0.16095\ (\mathrm{CID})
\end{aligned}
$$

<u>VIS (EQ B)</u>

$$
\begin{aligned}
= 0.37861 &- 0.00033570\ (\mathrm{XA7}) - 0.37294\ (\mathrm{CID}) \\
&+ 0.0091678\ (\mathrm{XCLL}) + 0.0059548\ (\mathrm{DHS}) \\
&- 0.000036143\ (\mathrm{XEL}) + 0.00032472\ (\mathrm{XATS7}) \\
&- 0.023610\ (\mathrm{VS}) + 0.0041583\ (\mathrm{DTS7})
\end{aligned}
$$

<u>TCA (EQ B)</u>

$$
\begin{aligned}
= 1.0871 &+ 0.0085472\ (\mathrm{XS5}) + 0.000077067\ (\mathrm{XEL}) \\
&- 0.0093168\ (\mathrm{H7}) + 0.0012239\ (\mathrm{ATS5}) \\
&- 0.0097330\ (\mathrm{XCLL}) - 0.00023202\ (\mathrm{XATS5}) \\
&- 0.0082604\ (\mathrm{DH7}) + 0.0080568\ (\mathrm{A7}) \\
&+ 0.037005\ (\mathrm{VS}) + 0.12514\ (\mathrm{CID})
\end{aligned}
$$

<u>PCP (EQ B)</u>

$$
\begin{aligned}
= 2.1247 &+ 0.014139\ (\mathrm{V7}) - 0.0064270\ (\mathrm{XCLL}) \\
&- 0.0020252\ (\mathrm{H7}) - 0.00012222\ (\mathrm{XV5T}) \\
&+ 0.000015770\ (\mathrm{XEL}) + 0.0053232\ (\mathrm{XCLN}) \\
&+ 0.0077387\ (\mathrm{VS}) + 0.00097715\ (\mathrm{A7}) \\
&+ 0.000077037\ (\mathrm{XA7}) - 0.000063019\ (\mathrm{XATS7})
\end{aligned}
$$

<u>IOC (EQ B)</u>

$$
\begin{aligned}
= -3.8080 &- 0.00022968\ (\mathrm{XA5}) - 0.000094660\ (\mathrm{XEL}) \\
&- 0.041337\ (\mathrm{VS}) + 0.0079807\ (\mathrm{H7}) \\
&+ 0.011499\ (\mathrm{XCLL}) - 0.0077854\ (\mathrm{A5}) \\
&- 0.28334\ (\mathrm{CID}) + 0.0081017\ (\mathrm{DH7}) \\
&+ 0.00024515\ (\mathrm{XATS5}) - 0.034690\ (\mathrm{V5})
\end{aligned}
$$

---

[7]Notation in parentheses beside numerical coefficients designates selected predictor. Predictor notation is identified in Appendix II.

Specification Equations - Season IV (Oct - Dec)[7]

Predictor Set C: Utilizing predictors derived from 1000-mb, 700-mb, and 500-mb Heights, Climatology, Coastal and Terrain Terms plus Radiation Terms.

CIG (EQ C)

$$
\begin{aligned}
= -\ 7.1532 &- 0.0064206\ (\mathrm{XS5}) &&- 0.000079566\ (\mathrm{XEL}) \\
&- 0.038407\ (\mathrm{VS}) &&+ 0.0071142\ (\mathrm{H7}) \\
&+ 0.0094852\ (\mathrm{XCLL}) &&- 0.0042809\ (\mathrm{A5}) \\
&+ 0.015615\ (\mathrm{STM}) &&+ 0.0072585\ (\mathrm{DH7}) \\
&+ 0.0063645\ (\mathrm{XSTS5}) &&- 0.17696\ (\mathrm{CID})
\end{aligned}
$$

VIS (EQ C)

$$
\begin{aligned}
= -\ .020895 &- 0.00029877\ (\mathrm{XA7}) &&- 0.34619\ (\mathrm{CID}) \\
&+ 0.0092255\ (\mathrm{XCLL}) &&+ 0.024241\ (\mathrm{STM}) \\
&+ 0.0044247\ (\mathrm{DHS}) &&- 0.000041775\ (\mathrm{XEL}) \\
&+ 0.00022887\ (\mathrm{XATS7}) &&+ 0.0048805\ (\mathrm{THEAT}) \\
&- 0.026080\ (\mathrm{VS}) &&+ 0.16526\ (\mathrm{TBSR})
\end{aligned}
$$

TCA (EQ C)

$$
\begin{aligned}
= 9.3657 &+ 0.0083372\ (\mathrm{XS5}) &&+ 0.000080799\ (\mathrm{XEL}) \\
&- 0.0092903\ (\mathrm{H7}) &&+ 0.0016544\ (\mathrm{ATS5}) \\
&- 0.0090886\ (\mathrm{XCLL}) &&- 0.015882\ (\mathrm{STM}) \\
&- 0.00022846\ (\mathrm{XATS5}) &&- 0.0082772\ (\mathrm{DH7}) \\
&+ 0.0076757\ (\mathrm{A7}) &&+ 0.035016\ (\mathrm{VS})
\end{aligned}
$$

PCP (EQ C)

No change from Equation B.

IOC (EQ C)

$$
\begin{aligned}
= -\ 4.9455 &- 0.00021588\ (\mathrm{XA5}) &&- 0.000098113\ (\mathrm{XEL}) \\
&- 0.046808\ (\mathrm{VS}) &&+ 0.026352\ (\mathrm{STM}) \\
&+ 0.0087646\ (\mathrm{H7}) &&- 0.0058477\ (\mathrm{A5}) \\
&+ 0.011554\ (\mathrm{XCLL}) &&- 0.30932\ (\mathrm{CID}) \\
&+ 0.0087292\ (\mathrm{DH7}) &&+ 0.00022730\ (\mathrm{XATS5})
\end{aligned}
$$

---

[7] Notation in parentheses beside numerical coefficients designates selected predictor. Predictor notation is identified in Appendix II.

APPENDIX II

NOTATIONS AND DEFINITIONS OF SELECTED PREDICTORS

PREDICTOR NOTATION	DEFINITION OF PREDICTOR
STM	Local time; sun at zenith at 1200. $STM = (\text{Time in EST}) - [(\text{Longitude} - 75°)/15]$
SR	Time of sunrise in local (sun) as for STM. (SR can be obtained from tables and/or formulae available in nautical almanacs)
ST	Time of sunset: similar to SR. (ST was not selected as a predictor. It is listed to simplify definitions to follow.)
TOD	$TOD = 1$, if $SR \le STM \le ST$ $TOD = 0$, if $SR > STM > ST$
TBST	Time until sunset; $TBST = ST - STM$, if $TOD = 1$ $TBST = 0$, if $TOD = 0$
TAST	Time since sunset; $TAST = STM + 24 - ST$, if $STM < SR$ $TAST = 0$, if $TOD = 1$ $TAST = STM - ST$, if $STM > ST$
TBSR	Time until sunrise; $TBSR = SR - STM$, if $STM < SR$ $TBSR = 0$, if $TOD = 1$
DURD	Duration of daylight; $DURD = ST - SR$
HTGV	Heating parameter $HTGV = 0$, if $TOD = 0$ $HTGV = TASR$, if $TOD = 1$ and $STM \le 12$ $HTGV = TBST$, if $TOD = 1$ and $STM > 12$
RADN	Radiation parameter; $RADN = HTGV$, if $TOD = 1$ $RADN = -CLGV$, if $TOD = 0$ where $CLGV = TAST$ if $STM > ST$ $= TBSR$ if $STM < SR$
THEAT	Total heating parameter: $THEAT = 0$ if $TOD = 0$ $THEAT = 1/2\,(TASR)^2$ if $TOD = 1$ and $STM \le 12$ $THEAT = (12 - SR)^2 - 1/2\,(ST - STM)^2$ if $TOD = 1$ and $STM > 12$
HS	1000-mb height[8]

[8] In deca feet.

H7	700-mb height[8]	
H5	500-mb height[8]	
DHS	24-hour change in 1000-mb height[8]	
DH7	24-hour change in 700-mb height[8]	
DH5	24-hour change in 500-mb height[8]	
TS7	1000—700-mb thickness[8]	
T75	700—500-mb thickness[8]	
DTS7	24-hour change in 1000—700-mb thickness[8]	
AS	1000-mb height anomaly[8]	$AS = HS - \overline{HS}$ [9]
A7	700-mb height anomaly[8]	$A7 = H7 - \overline{H7}$ [9]
A5	500-mb height anomaly[8]	$A5 = H5 - \overline{H5}$ [9]
SS	1000-mb height standardized anomaly	$SS = AS/\sigma\ (HS)$
S5	500-mb height standardized anomaly	$S5 = A5/\sigma\ (H5)$
ATS5	1000—500-mb thickness anomaly	$ATS5 = TS5 - \overline{TS5} = A5 - AS$
AT75	700—500-mb thickness anomaly	$AT75 = T75 - \overline{T75} = A5 - A7$
STS5	1000—500-mb thickness standardized anomaly	$STS5 = ATS5/\sigma\ (TS5)$ [10]
ST75	700—500-mb thickness standardized anomaly	$ST75 = AT75/\sigma\ (T75)$
STBA	Stability index derived from anomalies	$STBA = ATS7 - AT75$
STBS	Stability index derived from standardized anomalies	$STBS = STS7 - ST75$ [10]

---

8. In deca feet.

9. The mean and standard deviation of a variable (at a given time and place) are indicated respectively by a bar and the symbol σ, e.g., HS, σ (HS).

10. TS5 represents thickness 1000 mb to 500 mb
ATS7 represents thickness anomaly 1000 mb to 700 mb
ATS5 represents thickness anomaly 1000 mb to 500 mb
STS7 represents thickness standardized anomaly 1000 mb to 700 mb.

STVT	Stability index derived from assumed mean vertical temperatures STVT = 0.02866TS7 - 0.03038T75
VS	Relative vorticity 1000 mb[11]
V7	Relative vorticity 700 mb[11]
V5	Relative vorticity 500 mb[11]
XDH5	Advection of DH5 in the 500-mb flow[12]
XV7T	Advection of V7 in the 1000—500-mb thickness field[12]
XV5T	Advection of V5 in the 1000—500-mb thickness field[12]
XDTS5	Advection of DTS5 (i.e., 24-hour change in 1000—500-mb thickness) in the mean 1000—500-mb flow[12]
XDTS7	Advection of DTS7 (i.e., 24-hour change in 1000—700-mb thickness) in the mean 1000—700-mb flow[12]
XAS	Advection of AS (i.e., 1000-mb height anomaly) in the 1000-mb flow[12]
XA7	Advection of A7 (i.e., 700-mb height anomaly) in the 700-mb flow[12]
XA5	Advection of A5 (i.e., 500-mb height anomaly) in the 500-mb flow[12]
XS5	Advection of S5 (i.e., 500-mb height standardized anomaly) in the 500-mb flow[12]
XATS5	Advection of ATS5 (i.e., 1000—500-mb thickness anomaly) in the mean 1000—500-mb flow[12]
XATS7	Advection of ATS7 (i.e., 1000—700-mb thickness anomaly) in the mean 1000—700-mb flow[12]

---

11. The relative vorticity at a point was computed by subtracting the space-mean value (obtained from the height values at the 4 surrounding JNWP grid points) from the height value at the given point.

12. The advection of a variable X is computed from 4 surrounding points A, B, C, D as follows (where HA is the height at point A)

$$\text{Advection of } X = [H(A) - H(B)]\,[X(C) - X(D)] - [H(C) - H(D)]\,[X(A) - X(B)]$$

XSTS5 — Advection of STS5 (i.e., 1000—500-mb thickness standardized anomaly) in the mean 1000—500-mb flow[12]

XSTS7 — Advection of STS7 (i.e., 1000—700-mb thickness standardized anomaly) in the mean 1000—700-mb flow[12]

XST75 — Advection of ST75 (i.e., 700—500-mb thickness standardized anomaly) in the mean 700—500-mb flow[12]

XSTBA — Stability change from advection of thickness anomalies

$$XSTBA = XATS7 - XAT75$$

XEL — Index of orographically induced vertical motion. Computed from the advection formula[12], where X represents the terrain heights at the 4 surrounding points.

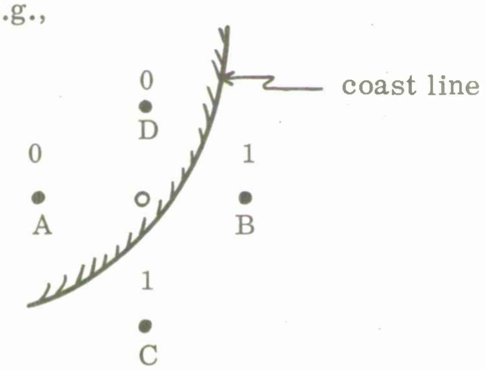
CID — A zero-one, or dummy, variable indicating that the grid point is or is not influenced by a major moisture source. CID = 1 if the point is influenced by a major moisture source. CID = 0 if the point is not so influenced.

XCLL — Coastal effect linear:

If CID = 0, SCLL = 0

If CID = 1, the 4 surrounding grid points are assigned values of 1 or 0 according to whether there is or is not a moisture source (lake, ocean, etc.) in the direction of that grid point which effects the central grid point. XCLL is then computed as the "Advection" of the assigned values by the 1000-mb flow. If XCLL < 0, the 1000-mb flow has a component from the moisture source toward the central grid point. If XCLL > 0, the component is away from the central grid point.

E.g.,



$$XCLL = [(HS_A - HS_B((1 - 0)] - [(HS_C - HS_D) (0 - 1)]$$

---

[12] The advection of a variable X is computed from 4 surrounding points A, B, C, D as follows (where HA is the height at point A)

$$\text{Advection of } X = [H(A) - H(B)] [X(C) - X(D)] - [H(C) - H(D)] [X(A) - X(B)]$$

XCLN	Coastal effect, segmented; If XCLL ≥ 0, XCLN $=$ XCLL If XCLL < 0, XCLN $= 0$
XCLD	A zero-one, or dummy, variable indicating on-shore flow (0) or off-shore flow (1).

APPENDIX III

CONTINGENCY TABLES

TABLE II
CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF CEILING

Season: Jan. - Mar. Data sample: Developmental

	OBSERVED CEILING CATEGORIES								
	CIG = UNL		UNL ≠ CIG ≥ 5000		5000 > CIG ≥ 1500		1500 > CIG		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.80	152	.85	15	.08	10	.06	2	.01	179
.60	223	.82	23	.08	22	.08	4	.02	272
.40	458	.78	50	.09	62	.10	18	.03	588
.20	779	.71	156	.14	125	.11	42	.04	1102
.00	932	.58	297	.19	248	.15	122	.08	1599
-.20	852	.45	404	.21	377	.20	258	.14	1891
-.40	328	.29	277	.24	269	.23	274	.24	1148
-.60	150	.21	163	.23	174	.25	221	.31	708
-.80	63	.17	60	.16	100	.27	147	.40	370
-1.00	20	.11	21	.12	49	.27	91	.50	181
-1.50	31	.14	18	.09	48	.23	112	.54	209
<-1.50	5	.06	2	.03	14	.16	64	.75	85
Climatological totals and frequencies	3993	.48	1486	.18	1498	.18	1355	.16	8332

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using CIG index table of probabilities) = .61

$\bar{p}$ score (using climatological probabilities) = .68

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.
$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE III

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF CEILING

Season: Jan. - Mar. Data sample: Independent

	OBSERVED CEILING CATEGORIES								
	CIG = UNL		UNL ≠ CIG ≥ 5000		5000 > CIG ≥ 1500		1500 > CIG		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.80	80	.89	3	.03	6	.07	1	.01	90
.60	141	.82	15	.09	13	.07	4	.02	173
.40	371	.76	58	.12	49	.10	7	.02	485
.20	648	.69	130	.14	129	.14	32	.03	939
.00	953	.59	284	.18	249	.16	120	.07	1606
-.20	762	.42	409	.23	350	.19	298	.16	1819
-.40	415	.30	291	.21	310	.23	346	.26	1362
-.60	138	.20	161	.23	178	.26	213	.31	690
-.80	38	.11	84	.24	67	.19	158	.46	347
-1.00	15	.09	25	.14	37	.21	99	.56	176
-1.50	5	.04	12	.10	19	.16	84	.70	120
<-1.50	0	.00	1	.03	5	.14	30	.83	36
Climatological totals and frequencies	3566	.45	1473	.19	1412	.18	1392	.18	7843

[13] Relative frequency = (no. of cases) / (row total)

$\overline{p}$ score (using CIG index table of probabilities) = .63

$\overline{p}$ score (using climatological probabilities) = .70

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\overline{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE IV

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF VISIBILITY

Season: Jan. - Mar. Data sample: Developmental

	OBSERVED VISIBILITY CATEGORIES								
	VSBY ≥ 15		15 > VSBY ≥ 7		7 > VSBY ≥ 3		3 > VSBY		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.80	98	.82	20	.17	0	.00	1	.01	119
.50	293	.68	112	.26	23	.05	3	.01	431
.30	526	.62	246	.29	51	.06	23	.03	846
.10	825	.52	572	.36	138	.09	51	.03	1586
.00	473	.48	353	.36	105	.11	54	.05	985
-.10	422	.42	354	.35	147	.14	95	.09	1018
-.30	590	.32	741	.41	294	.16	192	.11	1817
-.80	291	.22	451	.35	289	.22	271	.21	1302
-1.00	15	.14	29	.27	25	.23	39	.36	108
<-1.00	9	.08	28	.23	28	.23	55	.46	120
Climatological totals and frequencies	3542	.43	2906	.35	1100	.13	784	.09	8332

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using VSBY index table of probabilities) = .64

$\bar{p}$ score (using climatological probabilities) = .67

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE V

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF VISIBILITY

Season: Jan. - Mar. Data sample: Independent

	OBSERVED VISIBILITY CATEGORIES								
	VSBY ≥ 15		15 > VSBY ≥ 7		7 > VSBY ≥ 3		3 > VSBY		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.80	50	.56	33	.37	6	.07	0	.00	89
.50	209	.56	139	.37	18	.05	6	.02	372
.30	297	.40	357	.49	57	.08	24	.03	735
.10	539	.40	612	.45	155	.11	54	.04	1360
.00	288	.33	415	.46	138	.15	52	.06	893
-.10	305	.33	418	.46	117	.13	73	.08	913
-.30	447	.25	877	.50	256	.15	183	.10	1763
-.80	277	.18	660	.43	308	.20	291	.19	1536
-1.00	6	.07	24	.29	23	.27	31	.37	84
<-1.00	4	.04	16	.16	26	.27	52	.53	98
Climatological totals and frequencies	2422	.31	3551	.45	1104	.14	766	.10	7843

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using VSBY index table of probabilities) = .67 $\bar{p}$ score (using climatological probabilities) = .70

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\overline{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE VI
CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF TOTAL CLD. AMT.

Season: Jan. - Mar.

Data sample: Developmental

	OBSERVED TOT. CLD. AMT. CATEGORIES								
	10/10		10/10 > TCA ≥ 6/10		6/10 > TCA				
$\hat{Y}$ range (lower limit)	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	Total cases by row
≥1.20	100	.92	2	.02	7	.06			109
.60	442	.82	45	.09	50	.09			537
.30	715	.73	114	.12	150	.15			979
.15	659	.63	116	.12	265	.25			1040
.05	433	.50	164	.19	268	.31			865
-.05	396	.43	171	.18	359	.39			926
-.20	421	.34	215	.18	586	.48			1222
-.60	436	.22	292	.15	1216	.63			1944
-1.00	77	.14	70	.12	417	.74			564
<-1.00	20	.14	11	.07	115	.79			146
Climatological totals and frequencies	3699	.44	1200	.15	3433	.41			8332

[13]Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using TCA index table of probabilities) = .52

$\bar{p}$ score (using climatological probabilities) = .61

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.
$\overline{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE VII

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF TOTAL CLD. AMT.

Season: Jan. – Mar. Data sample: Independent

	OBSERVED TOT. CLD. AMT. CATEGORIES								
	10/10		10/10 > TCA ≥ 6/10		6/10 TCA				
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥1.20	55	.98	1	.02	0	.00			56
.60	365	.86	26	.06	35	.08			426
.30	741	.72	131	.13	161	.15			1033
.15	601	.58	166	.16	270	.26			1037
.05	445	.51	167	.19	256	.30			868
–.05	400	.44	164	.18	350	.38			914
–.20	404	.35	189	.16	577	.49			1170
–.60	445	.25	265	.15	1084	.60			1794
–1.00	56	.13	51	.11	338	.76			445
<–1.00	4	.04	11	.11	85	.85			100
Climatological totals and frequencies	3516	.45	1171	.15	3156	.40			7843

[13]Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using TCA index table of probabilities) = .53

$\bar{p}$ score (using climatological probabilities) = .61

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE VIII

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF IOC

Season: Jan. - Mar. Data sample: Developmental

	OBSERVED IOC CATEGORIES[14]								
	4		3		2		1		
$\hat{Y}$ range (lower limit)	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	Total cases by row
≥5.0	114	.83	13	.09	8	.06	2	.02	137
4.6	359	.79	45	.10	38	.08	10	.02	452
4.2	939	.70	176	.13	168	.13	60	.04	1343
3.8	1365	.52	507	.19	474	.18	262	.10	2608
3.4	691	.31	490	.22	530	.24	504	.23	2215
3.0	171	.18	195	.21	227	.24	352	.37	945
2.6	50	.14	40	.11	88	.25	174	.49	352
2.0	27	.14	15	.08	36	.19	116	.60	194
< 2.0	5	.06	2	.02	13	.15	66	.77	86
Climatological totals and frequencies	3721	.45	1483	.18	1582	.19	1546	.18	8332

[13]Relative frequency = (no. of cases) / (row total)

[14]For definitions of IOC Categories, see Table XL.

$\bar{p}$ score (using IOC index table of probabilities) = .63 $\bar{p}$ score (using climatological probabilities) = .70

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.
$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE IX
CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF IOC

Season: Jan. - Mar. Data sample: Independent

	OBSERVED IOC CATEGORIES [14]								
	4		3		2		1		
$\hat{Y}$ range (lower limit)	No. of cases	Relative [13] frequency	No. of cases	Relative [13] frequency	No. of cases	Relative [13] frequency	No. of cases	Relative [13] frequency	Total cases by row
≥5.0	66	.85	3	.04	6	.08	3	.03	78
4.6	229	.78	36	.12	23	.08	5	.02	293
4.2	784	.69	163	.14	151	.13	41	.04	1139
3.8	1297	.52	488	.20	432	.17	267	.11	2484
3.4	747	.31	537	.22	558	.23	600	.24	2442
3.0	150	.16	217	.23	226	.24	341	.37	934
2.6	24	.07	60	.19	57	.18	181	.56	322
2.0	3	.03	12	.11	15	.14	81	.72	111
< 2.0	0	.00	1	.02	5	.12	34	.86	40
Climatological totals and frequencies	3300	.42	1517	.19	1473	.19	1553	.20	7843

[13] Relative frequency = (no. of cases) / (row total)

[14] For definitions of IOC Categories, see Table XL.

$\bar{p}$ score (using IOC index table of probabilities) = .65

$\bar{p}$ score (using climatological probabilities) = .71

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.
$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE X

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF PRECIPITATION

Season: Jan. - Mar.

Data sample: Developmental

	OBSERVED PRECIPITATION CATEGORIES								
	PRECIP.		NO PRECIP.						
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.60	112	.82	24	.18					136
.40	225	.52	206	.48					430
.20	578	.28	1515	.72					2093
.10	283	.11	2202	.89					2485
.00	123	.05	2317	.95					2440
< .00	20	.03	727	.97					747
Climatological totals and frequencies	1341	.16	6991	.84					8332

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using PRECIP. index table of probabilities) = .22

$\bar{p}$ score (using climatological probabilities) = .27

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XI

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF PRECIPITATION

Season: Jan. - Mar. **Data sample:** Independent

	OBSERVED PRECIPITATION CATEGORIES								
	PRECIP.		NO PRECIP.						
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.60	63	.72	24	.28					87
.40	201	.56	158	.44					359
.20	596	.27	1649	.73					2245
.10	287	.11	2313	.89					2600
.00	95	.05	1936	.95					2031
< .00	21	.04	500	.96					521
Climatological totals and frequencies	1263	.16	6580	.84					7843

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using PRECIP. index table of probabilities) = .23

$\bar{p}$ score (using climatological probabilities) = .27

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XII

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF CEILING

Season: Apr. - Jun. Data sample: Developmental

	OBSERVED CEILING CATEGORIES								
	CIG = UNL		UNL ≠ CIG ≥ 5000		5000 > CIG ≥ 1500		1500 > CIG		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.80	149	.86	13	.07	10	.06	1	.01	173
.50	962	.82	146	.12	53	.05	17	.01	1178
.30	1709	.70	480	.20	165	.07	71	.03	2425
.00	2034	.53	1058	.28	490	.13	239	.06	3821
-.20	350	.33	345	.32	228	.22	142	.13	1065
-.40	120	.22	180	.32	120	.22	133	.24	553
-.60	53	.17	87	.27	84	.27	91	.29	315
-.80	19	.11	57	.32	42	.24	59	.33	177
-1.10	13	.09	28	.20	40	.28	61	.43	142
<-1.10	16	.10	22	.15	31	.21	80	.54	149
Climatological totals and frequencies	5425	.54	2416	.24	1263	.13	894	.09	9998

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using CIG index table of probabilities) = .56

$\bar{p}$ score (using climatological probabilities) = .62

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XIII

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF CEILING

Season: Apr. – Jun. **Data sample:** Independent

	OBSERVED CEILING CATEGORIES								
	CIG = UNL		UNL ≠ CIG ≥ 5000		5000 > CIG ≥ 1500		1500 > CIG		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.80	83	.78	11	.10	12	.11	1	.01	107
.50	688	.79	108	.12	59	.07	21	.02	876
.30	1618	.69	456	.20	167	.07	86	.04	2327
.00	2287	.53	1096	.25	577	.13	398	.09	4358
-.20	487	.33	441	.30	302	.21	232	.16	1462
-.40	153	.24	198	.30	139	.21	164	.25	654
-.60	48	.15	88	.28	87	.27	94	.30	317
-.80	30	.18	49	.28	42	.24	52	.30	173
-1.10	13	.08	38	.25	40	.26	62	.41	153
<-1.10	3	.03	12	.10	24	.20	81	.67	120
Climatological totals and frequencies	5410	.51	2497	.24	1449	.14	1191	.11	10547

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using CIG index table of probabilities) = .60

$\bar{p}$ score (using climatological probabilities) = .65

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\overline{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XIV
CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF VISIBILITY

Season: Apr. - Jun. **Data sample:** Developmental

	OBSERVED VISIBILITY CATEGORIES								
	VSBY ≥ 15		15 > VSBY ≥ 7		7 > VSBY ≥ 3		3 > VSBY		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.80	252	.84	44	.15	3	.01	1	.00	300
.50	1530	.75	427	.21	68	.03	17	.01	2042
.30	1297	.65	528	.26	137	.07	41	.02	2003
.10	1519	.49	1226	.40	282	.09	70	.02	3097
.00	469	.39	547	.45	142	.12	53	.04	1211
-.20	272	.34	312	.39	152	.19	69	.08	805
-.50	121	.27	139	.32	110	.25	71	.16	441
<-.50	21	.21	16	.16	31	.31	31	.32	99
Climatological totals and frequencies	5481	.55	3239	.32	925	.09	353	.04	9998

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using VSBY index table of probabilities) = .55

$\bar{p}$ score (using climatological probabilities) = .58

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.
$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XV

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF VISIBILITY

Season: Apr. - Jun. Data sample: Independent

	OBSERVED VISIBILITY CATEGORIES								
	VSBY ≥ 15		15 > VSBY ≥ 7		7 > VSBY ≥ 3		3 > VSBY		
$\hat{Y}$ range (lower limit)	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	Total cases by row
≥.80	233	.80	55	.19	3	.01	1	.00	292
.50	1079	.59	588	.32	139	.07	35	.02	1841
.30	971	.49	780	.39	186	.09	58	.03	1995
.10	1032	.35	1542	.53	279	.09	78	.03	2931
.00	520	.32	901	.55	158	.09	62	.04	1641
-.20	374	.30	626	.50	168	.13	83	.07	1251
-.50	125	.30	134	.32	96	.23	62	.15	417
<-.50	24	.14	59	.33	47	.26	49	.27	179
Climatological totals and frequencies	4358	.41	4685	.45	1076	.10	428	.04	10547

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using VSBY index table of probabilities) = .62 $\bar{p}$ score (using climatological probabilities) = .65

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.
$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XVI
CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF TOTAL CLD. AMT.

Season: Apr. - Jun. Data sample: Developmental

	OBSERVED TOT. CLD. AMT. CATEGORIES								
	10/10		10/10 > TCA ≥ 6/10		6/10 > TCA				
$\hat{Y}$ range (lower limit)	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	Total cases by row
≥.80	298	.84	26	.07	32	.09			356
.50	260	.75	48	.14	38	.11			346
.30	308	.68	77	.17	68	.15			453
.15	319	.58	114	.21	114	.21			547
.00	477	.52	221	.24	213	.24			911
-.20	887	.33	697	.26	1080	.41			2664
-.40	523	.19	666	.24	1576	.57			2765
-.80	216	.13	289	.17	1189	.70			1694
<-.80	19	.07	45	.17	198	.76			262
Climatological totals and frequencies	3307	.33	2183	.22	4508	.45			9998

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using TCA index table of probabilities) = .56 $\bar{p}$ score (using climatological probabilities) = .64

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.
$\overline{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XVII

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF TOTAL CLD. AMT.

Season: Apr. - Jun. Data sample: Independent

	OBSERVED TOT. CLD. AMT. CATEGORIES								
	10/10		10/10 > TCA ≥ 6/10		6/10 > TCA				
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.80	242	.83	29	.10	20	.07			291
.50	246	.79	38	.12	28	.09			312
.30	323	.71	65	.15	65	.14			453
.15	389	.62	132	.21	106	.17			627
.00	515	.48	267	.25	283	.27			1065
-.20	931	.30	905	.29	1256	.41			3092
-.40	550	.18	751	.25	1701	.57			3002
-.80	224	.16	233	.16	987	.68			1444
<-.80	33	.13	29	.11	199	.76			261
Climatological totals and frequencies	3453	.33	2449	.23	4645	.44			10547

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using TCA index table of probabilities) = .57

$\bar{p}$ score (using climatological probabilities) = .65

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XVIII

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF IOC

Season: Apr. - Jun. Data sample: Developmental

	OBSERVED IOC CATEGORIES [14]								
	4		3		2		1		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency [13]	No. of cases	Relative frequency [13]	No. of cases	Relative frequency [13]	No. of cases	Relative frequency [13]	Total cases by row
≥4.80	274	.84	33	.10	15	.05	4	.01	326
4.40	1793	.71	476	.19	165	.07	70	.03	2504
4.00	2402	.54	1178	.26	609	.14	282	.06	4471
3.60	508	.31	511	.31	373	.22	270	.16	1662
3.20	94	.16	170	.29	145	.25	175	.30	584
2.80	24	.10	61	.26	63	.27	86	.37	234
<2.80	20	.09	32	.15	48	.22	117	.54	217
Climatological totals and frequencies	5115	.51	2461	.25	1418	.14	1004	.10	9998

[13] Relative frequency = (no. of cases) / (row total)

[14] For definitions of IOC Categories, see Table XL.

$\bar{p}$ score (using IOC index table of probabilities) = .59

$\bar{p}$ score (using climatological probabilities) = .65

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XIX

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF IOC

Season: Apr. - Jun. Data sample: Independent

	OBSERVED IOC CATEGORIES [14]								
	4		3		2		1		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency [13]	No. of cases	Relative frequency [13]	No. of cases	Relative frequency [13]	No. of cases	Relative frequency [13]	Total cases by row
≥4.80	171	.79	19	.09	19	.09	6	.03	215
4.40	1458	.69	410	.20	167	.08	69	.03	2104
4.00	2638	.52	1264	.25	682	.14	446	.09	5030
3.60	691	.32	647	.30	439	.21	371	.17	2148
3.20	96	.16	162	.27	165	.28	177	.29	600
2.80	33	.13	69	.28	51	.20	97	.39	250
<2.80	9	.05	34	.17	43	.21	114	.57	200
Climatological totals and frequencies	5096	.48	2605	.25	1566	.15	1280	.12	10547

[13] Relative frequency = (no. of cases) / (row total)

[14] For definitions of IOC Categories, see Table XL.

$\bar{p}$ score (using IOC index table of probabilities) = .63 $\bar{p}$ score (using climatological probabilities) = .67

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\overline{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XX
CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF PRECIPITATION

Season: Apr. - Jun. | Data sample: Developmental

	OBSERVED PRECIPITATION CATEGORIES								
	PRECIP.		NO PRECIP.						
$\hat{Y}$ range (lower limit)	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	Total cases by row
≥.45	83	.60	56	.40					139
.35	90	.47	100	.53					190
.24	150	.33	306	.67					456
.18	141	.24	451	.76					592
.12	152	.12	1109	.88					1261
.06	178	.06	2812	.94					2990
.00	99	.03	3026	.97					3125
<.00	18	.01	1227	.99					1245
Climatological totals and frequencies	911	.09	9087	.91					9998

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using PRECIP. index table of probabilities) = .14

$\bar{p}$ score (using climatological probabilities) = .17

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\overline{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXI

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF PRECIPITATION

Season: Apr. - Jun. Data sample: Independent

	OBSERVED PRECIPITATION CATEGORIES								
	PRECIP.		NO PRECIP.						
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.45	87	.59	60	.41					147
.35	84	.47	93	.53					177
.24	156	.28	397	.72					553
.18	123	.16	665	.84					788
.12	205	.12	1565	.88					1770
.06	175	.06	2984	.94					3159
.00	82	.03	2880	.97					2962
<.00	20	.02	971	.98					991
Climatological totals and frequencies	932	.09	9615	.91					10547

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using PRECIP. index table of probabilities) = .14

$\bar{p}$ score (using climatological probabilities) = .16

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\overline{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXII

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF CEILING

Season: Jul. - Sep.

Data sample: Developmental

	OBSERVED CEILING CATEGORIES								
	CIG = UNL		UNL ≠ CIG ≥ 5000		5000 > CIG ≥ 1500		1500 > CIG		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.80	225	.90	17	.07	8	.03	1	.00	251
.60	831	.83	136	.14	21	.02	12	.01	1000
.40	2074	.73	619	.22	114	.04	41	.01	2848
.20	1871	.61	842	.27	230	.08	125	.04	3068
.00	707	.47	475	.32	188	.13	124	.08	1494
-.20	235	.34	234	.34	117	.17	105	.15	691
-.40	85	.25	121	.35	65	.19	73	.21	344
-.80	36	.17	57	.27	43	.20	76	.36	212
<-.80	17	.19	15	.17	21	.24	36	.40	89
Climatological totals and frequencies	6081	.61	2516	.25	807	.08	593	.06	9997

[13]Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using CIG index table of probabilities) = .52

$\bar{p}$ score (using climatological probabilities) = .56

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXIII
CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF CEILING

Season: Jul. - Sep. Data sample: Independent

	OBSERVED CEILING CATEGORIES								
	CIG = UNL		UNL ≠ CIG ≥ 5000		5000 > CIG ≥ 1500		1500 > CIG		
$\hat{Y}$ range (lower limit)	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	Total cases by row
≥.80	146	.80	16	.09	16	.09	5	.02	183
.60	603	.78	116	.15	45	.06	14	.01	778
.40	1984	.70	599	.21	176	.06	89	.03	2848
.20	2055	.59	922	.26	321	.09	191	.06	3489
.00	787	.46	545	.32	210	.12	185	.10	1727
-.20	247	.32	286	.37	119	.15	129	.16	781
-.40	98	.27	113	.31	64	.18	85	.24	360
-.80	37	.15	69	.29	53	.22	83	.34	242
<-.80	10	.09	21	.20	28	.26	48	.45	107
Climatological totals and frequencies	5967	.57	2687	.25	1032	.10	829	.08	10515

[13]Relative frequency = (no. of cases) / (row total)

$\overline{p}$ score (using CIG index table of probabilities) = .56 $\overline{p}$ score (using climatological probabilities) = .60

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.
$\overline{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXIV

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF VISIBILITY

Season: Jul. - Sep.

Data sample: Developmental

	OBSERVED VISIBILITY CATEGORIES								
	VSBY ≥ 15		15 > VSBY ≥ 7		7 > VSBY ≥ 3		3 > VSBY		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.80	367	.91	28	.07	4	.01	3	.01	402
.50	1556	.78	377	.19	42	.02	26	.01	2001
.30	1360	.68	509	.26	88	.04	38	.02	1995
.10	1099	.44	1045	.41	283	.11	94	.04	2521
.00	403	.33	601	.49	170	.14	46	.04	1220
-.10	352	.38	375	.41	148	.16	44	.05	919
-.30	314	.40	282	.36	124	.16	72	.08	792
<-.30	45	.31	50	.34	33	.22	19	.13	147
Climatological totals and frequencies	5496	.55	3267	.33	892	.09	342	.03	9997

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using VSBY index table of probabilities) = .53

$\bar{p}$ score (using climatological probabilities) = .58

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXV

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF VISIBILITY

Season: Jul. - Sep. Data sample: Independent

	OBSERVED VISIBILITY CATEGORIES								
	VSBY ≥ 15		15 > VSBY ≥ 7		7 > VSBY ≥ 3		3 > VSBY		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.80	322	.84	55	.14	5	.01	3	.01	385
.50	1113	.54	684	.33	206	.10	73	.03	2076
.30	1074	.49	817	.37	244	.10	88	.04	2223
.10	1143	.38	1436	.48	311	.10	134	.04	3024
.00	278	.21	790	.61	168	.13	65	.05	1301
-.10	155	.18	521	.62	126	.15	44	.05	846
-.30	84	.16	275	.53	111	.21	44	.10	514
<-.30	22	.15	64	.44	35	.24	25	.17	146
Climatological totals and frequencies	4191	.40	4642	.44	1206	.11	476	.05	10515

[13]Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using VSBY index table of probabilities) = .64 $\bar{p}$ score (using climatological probabilities) = .67

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXVI

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF TOTAL CLD. AMT.

Season: Jul. - Sep. Data sample: Developmental

	OBSERVED TOT. CLD. AMT. CATEGORIES								
	10/10		10/10 > TCA ≥ 6/10		6/10 > TCA				
$\hat{Y}$ range (lower limit)	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	Total cases by row
≥.50	149	.72	27	.13	31	.15			207
.30	160	.63	46	.18	48	.19			254
.15	189	.57	73	.22	72	.21			334
.00	270	.44	151	.25	192	.31			613
-.20	587	.32	510	.28	720	.40			1817
-.40	553	.19	753	.26	1600	.55			2906
-.80	394	.12	668	.20	2233	.68			3295
<-.80	26	.05	71	.12	474	.83			571
Climatological totals and frequencies	2328	.23	2299	.23	5370	.54			9997

[13]Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using TCA index table of probabilitics) = .55 $\bar{p}$ score (using climatological probabilitics) = .60

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\overline{P}$ scores for an independent data sample are computed using probabilitics (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXVII

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF TOTAL CLD. AMT.

Season: Jul. - Sep. Data sample: Independent

	OBSERVED TOT. CLD. AMT. CATEGORIES								
	10/10		10/10 > TCA ≥ 6/10		6/10 > TCA				
$\hat{Y}$ range (lower limit)	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	Total cases by row
≥.50	202	.75	40	.15	26	.10			268
.30	147	.64	46	.20	37	.16			230
.15	195	.55	89	.25	72	.20			356
.00	327	.43	207	.27	229	.30			763
-.20	582	.27	645	.30	925	.43			2152
-.40	581	.18	858	.27	1721	.55			3160
-.80	445	.15	662	.22	1926	.63			3033
<-.80	40	.07	88	.16	425	.77			553
Climatological totals and frequencies	2519	.24	2635	.25	5361	.51			10515

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using TCA index table of probabilities) = .58 $\bar{p}$ score (using climatological probabilities) = .62

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\overline{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXVIII

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF IOC

Season: Jul. - Sep. Data sample: Developmental

	OBSERVED IOC CATEGORIES[14]								
	4		3		2		1		
$\hat{Y}$ range (lower limit)	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	Total cases by row
≥5.00	130	.88	12	.08	5	.03	1	.01	148
4.60	1311	.80	252	.15	51	.03	29	.02	1643
4.20	2924	.61	1312	.27	384	.08	189	.04	4809
3.80	1054	.43	750	.31	379	.15	273	.11	2456
3.40	178	.26	195	.29	148	.22	155	.23	676
3.00	30	.16	42	.23	36	.20	75	.41	183
2.60	9	.19	8	.16	11	.23	20	.42	48
<2.60	7	.20	5	.15	6	.18	16	.47	34
Climatological totals and frequencies	5643	.56	2576	.26	1020	.10	758	.08	9997

[13] Relative frequency = (no. of cases) / (row total)

[14] For definitions of IOC Categories, see Table XL.

$\overline{p}$ score (using IOC index table of probabilities) = .56 $\overline{p}$ score (using climatological probabilities) = .60

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\overline{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXIX

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF IOC

Season: Jul. - Sep. Data sample: Independent

	OBSERVED IOC CATEGORIES[14]								
	4		3		2		1		
$\hat{Y}$ range (lower limit)	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	Total cases by row
≥5.00	70	.77	11	.12	8	.09	2	.02	91
4.60	882	.68	267	.20	113	.09	44	.03	1306
4.20	3065	.58	1430	.27	499	.09	303	.06	5297
3.80	1151	.41	858	.31	426	.15	351	.13	2786
3.40	175	.24	233	.32	128	.18	185	.26	721
3.00	26	.12	46	.20	50	.22	103	.46	225
2.60	4	.07	8	.13	21	.34	28	.46	61
<2.60	2	.07	3	.11	7	.25	16	.57	28
Climatological totals and frequencies	5375	.51	2856	.27	1252	.12	1032	.10	10515

[13]Relative frequency = (no. of cases) / (row total)

[14]For definitions of IOC Categories, see Table XL.

$\overline{p}$ score (using IOC index table of probabilities) = .62 $\overline{p}$ score (using climatological probabilities) = .64

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.
$\overline{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXX
CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF CEILING

Season: Oct. - Dec.

Data sample: Developmental

	OBSERVED CEILING CATEGORIES								
	CIG = UNL		UNL ≠ CIG ≥ 5000		5000 > CIG ≥ 1500		1500 > CIG		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.80	244	.89	21	.08	8	.03	1	.00	274
.50	993	.83	110	.09	74	.06	18	.02	1195
.30	1392	.74	268	.14	143	.08	86	.04	1889
.00	2045	.57	786	.22	463	.13	282	.08	3576
-.30	582	.35	471	.28	358	.22	245	.15	1656
-.60	192	.24	197	.24	231	.28	197	.24	817
-.80	42	.17	49	.20	88	.35	69	.28	248
-1.10	22	.11	32	.16	54	.28	89	.45	197
<-1.10	14	.10	9	.06	35	.24	88	.60	146
Climatological totals and frequencies	5526	.55	1943	.19	1454	.15	1075	.11	9998

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using CIG index table of probabilities) = .56

$\bar{p}$ score (using climatological probabilities) = .62

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXXI

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF CEILING

Season: Oct. - Dec. Data sample: Independent

	OBSERVED CEILING CATEGORIES								
	CIG = UNL		UNL $\neq$ CIG $\geq$ 5000		5000 > CIG $\geq$ 1500		1500 > CIG		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.80	107	.80	8	.06	18	.13	1	.01	134
.50	686	.77	83	.10	82	.09	35	.04	886
.30	1334	.72	248	.13	188	.10	92	.05	1862
.00	2223	.57	773	.20	489	.13	391	.10	3876
-.30	768	.35	532	.24	467	.22	405	.19	2172
-.60	228	.23	225	.22	276	.28	269	.27	998
-.80	32	.10	61	.18	79	.24	158	.48	330
-1.10	14	.06	39	.17	66	.29	106	.48	225
<-1.10	10	.07	12	.08	42	.28	85	.57	149
Climatological totals and frequencies	5402	.51	1981	.19	1707	.16	1542	.14	10632

[13]Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using CIG index table of probabilities) = .60

$\bar{p}$ score (using climatological probabilities) = .66

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\overline{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXXII

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF VISIBILITY

Season: Oct. - Dec. Data sample: Developmental

	OBSERVED VISIBILITY CATEGORIES								
	VSBY ≥ 15		15 > VSBY ≥ 7		7 > VSBY ≥ 3		3 > VSBY		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.80	168	.84	28	.14	1	.01	2	.01	199
.50	898	.74	269	.22	27	.02	17	.02	1211
.30	1242	.63	563	.29	113	.06	38	.02	1956
.10	1003	.51	662	.33	203	.10	111	.06	1979
.00	575	.44	491	.38	156	.12	72	.06	1294
-.10	572	.38	647	.44	168	.11	99	.07	1486
-.30	379	.30	553	.44	195	.15	141	.11	1268
-.80	151	.28	168	.32	116	.22	95	.18	530
<-.80	12	.16	22	.29	19	.25	22	.30	75
Climatological totals and frequencies	5000	.50	3403	.34	998	.10	597	.06	9998

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using VSBY index table of probabilities) = .59

$\bar{p}$ score (using climatological probabilities) = .62

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXXIII

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF VISIBILITY

Season: Oct. - Dec. Data sample: Independent

	OBSERVED VISIBILITY CATEGORIES								
	VSBY ≥ 15		15 > VSBY ≥ 7		7 > VSBY ≥ 3		3 > VSBY		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.80	124	.76	37	.23	2	.01	0	.00	163
.50	618	.60	303	.30	69	.07	31	.03	1021
.30	775	.45	712	.41	166	.10	73	.04	1726
.10	778	.36	1015	.47	238	.11	127	.06	2158
.00	411	.27	844	.55	186	.12	94	.06	1535
-.10	432	.27	810	.51	195	.13	138	.09	1575
-.30	486	.29	747	.44	262	.15	186	.12	1681
-.80	142	.20	254	.37	171	.25	128	.18	695
<-.80	8	.10	17	.22	22	.28	31	.40	78
Climatological totals and frequencies	3774	.35	4739	.45	1311	.12	808	.08	10632

[13] Relative frequency = (no. of cases) / (row total)

$\overline{p}$ score (using VSBY index table of probabilities) = .66 $\overline{p}$ score (using climatological probabilities) = .69

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\overline{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXXIV

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF TOTAL CLD. AMT.

Season: Oct. - Dec. **Data sample:** Developmental

	OBSERVED TOT. CLD. AMT. CATEGORIES								
	10/10		10/10 > TCA ≥ 6/10		6/10 > TCA				
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥1.20	105	.88	6	.05	9	.07			120
.60	355	.80	37	.08	53	.12			445
.30	457	.67	94	.14	133	.19			684
.15	339	.62	76	.14	135	.24			550
.05	277	.55	81	.16	148	.29			506
-.05	275	.48	112	.20	186	.32			573
-.20	492	.44	209	.18	426	.38			1127
-.60	1051	.24	742	.17	2576	.59			4369
-1.00	149	.11	162	.12	1065	.77			1376
<-1.00	17	.07	20	.08	211	.85			248
Climatological totals and frequencies	3517	.35	1539	.15	4942	.50			9998

[13]Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using TCA index table of probabilities) = .52 $\bar{p}$ score (using climatological probabilities) = .61

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXXV

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF TOTAL CLD. AMT.

Season: Oct. - Dec. Data sample: Independent

	OBSERVED TOT. CLD. AMT. CATEGORIES								
	10/10		10/10 > TCA ≥ 6/10		6/10 > TCA				
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥1.20	112	.91	6	.05	5	.04			123
.60	455	.81	60	.11	46	.08			561
.30	606	.69	105	.12	168	.19			879
.15	406	.60	109	.16	158	.24			673
.05	338	.57	96	.16	162	.27			596
-.05	357	.50	134	.18	228	.32			719
-.20	578	.40	284	.19	590	.41			1452
-.60	1024	.24	758	.17	2538	.59			4320
-1.00	143	.13	142	.12	845	.75			1130
<-1.00	23	.13	18	.10	138	.77			179
Climatological totals and frequencies	4042	.38	1712	.16	4678	.46			10632

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using TCA index table of probabilities) = .54

$\bar{p}$ score (using climatological probabilities) = .62

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXXVI

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF IOC

Season: Oct. - Dec. Data sample: Developmental

	OBSERVED IOC CATEGORIES[14]								
	4		3		2		1		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥5.00	156	.90	10	.06	8	.04	0	.00	174
4.40	1582	.76	278	.13	169	.08	67	.03	2096
4.00	2300	.58	830	.21	489	.13	327	.08	3946
3.60	814	.36	577	.26	502	.22	368	.16	2261
3.20	198	.22	217	.25	243	.27	231	.26	889
2.80	49	.13	74	.20	112	.30	140	.37	375
2.40	15	.10	17	.11	36	.24	82	.55	150
<2.40	6	.05	5	.05	28	.26	68	.64	107
Climatological totals and frequencies	5120	.51	2008	.20	1587	.16	1283	.13	9998

[13]Relative frequency = (no. of cases) / (row total)

[14]For definitions of IOC Categories, see Table XL.

$\bar{p}$ score (using IOC index table of probabilities) = .60

$\bar{p}$ score (using climatological probabilities) = .66

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXXVII

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF IOC

Season: Oct. - Dec. Data sample: Independent

	OBSERVED IOC CATEGORIES[14]								
	4		3		2		1		
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥5.00	49	.73	4	.06	14	.21	0	.00	67
4.40	1154	.70	223	.13	202	.12	82	.05	1661
4.00	2382	.57	810	.20	546	.13	404	.10	4142
3.60	1046	.36	683	.24	591	.21	557	.19	2877
3.20	252	.22	260	.23	305	.28	321	.28	1138
2.80	48	.11	81	.18	119	.26	204	.45	452
2.40	10	.05	30	.16	46	.24	106	.55	192
<2.40	2	.02	5	.05	29	.28	67	.65	103
Climatological totals and frequencies	4943	.47	2096	.20	1852	.17	1741	.16	10632

[13]Relative frequency = (no. of cases) / (row total)

[14]For definitions of IOC Categories, see Table XL.

$\bar{p}$ score (using IOC index table of probabilities) = .64

$\bar{p}$ score (using climatological probabilities) = .69

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXXVIII

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF PRECIPITATION

Season: Oct. - Dec. Data sample: Developmental

	OBSERVED PRECIPITATION CATEGORIES								
	PRECIP.		NO PRECIP.						
$\hat{Y}$ range (lower limit)	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	No. of cases	Relative[13] frequency	Total cases by row
≥.50	72	.69	32	.31					104
.40	83	.56	66	.44					149
.30	133	.38	219	.62					352
.26	86	.28	218	.72					304
.20	149	.21	550	.79					699
.14	187	.16	1013	.84					1200
.08	168	.08	1887	.92					2055
.00	128	.03	3693	.97					3821
< .00	23	.02	1291	.98					1314
Climatological totals and frequencies	1029	.10	8969	.90					9998

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using PRECIP. index table of probabilities) = .16

$\bar{p}$ score (using climatological probabilities) = .18

$\bar{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\bar{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XXXIX

CONTINGENCY TABLE OF INDEX ($\hat{Y}$) VALUES vs. OBSERVED VALUES OF PRECIPITATION

Season: Oct. - Dec. Data sample: Independent

	OBSERVED PRECIPITATION CATEGORIES								
	PRECIP.		NO PRECIP.						
$\hat{Y}$ range (lower limit)	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	No. of cases	Relative frequency[13]	Total cases by row
≥.50	114	.62	70	.38					184
.40	117	.57	87	.43					204
.30	186	.41	265	.59					451
.26	101	.30	236	.70					337
.20	208	.26	604	.74					812
.14	213	.15	1205	.85					1418
.08	248	.10	2247	.90					2495
.00	142	.04	3723	.96					3865
<.00	16	.02	850	.98					866
Climatological totals and frequencies	1345	.13	9287	.87					10632

[13] Relative frequency = (no. of cases) / (row total)

$\bar{p}$ score (using PRECIP. index table of probabilities) = .19

$\bar{p}$ score (using climatological probabilities) = .22

$\overline{P}$ score can range from a minimum of 0.0 to a maximum of 2.0. A lower score is better.

$\overline{P}$ scores for an independent data sample are computed using probabilities (relative frequency) obtained from corresponding developmental-sample table.

TABLE XL

INTEGRATED OPERATING CONDITIONS (IOC) DEFINED

Category	Definition (CIG in feet, VSBY in miles)		
1	$CIG < 1500$	or	$VSBY < 3$
2	$5000 > CIG \geq 1500$	and	$VSBY \geq 3$
	or		
	$CIG \geq 1500$	and	$5 > VSBY \geq 3$
3	$UNL \neq CIG \geq 5000$	and	$VSBY \geq 5$
	or		
	$CIG \geq 5000$	and	$7 > VSBY \geq 5$
4	$CIG = UNL$	and	$VSBY \geq 7$

APPENDIX IV

SYNOPTIC MAPS, FEBRUARY

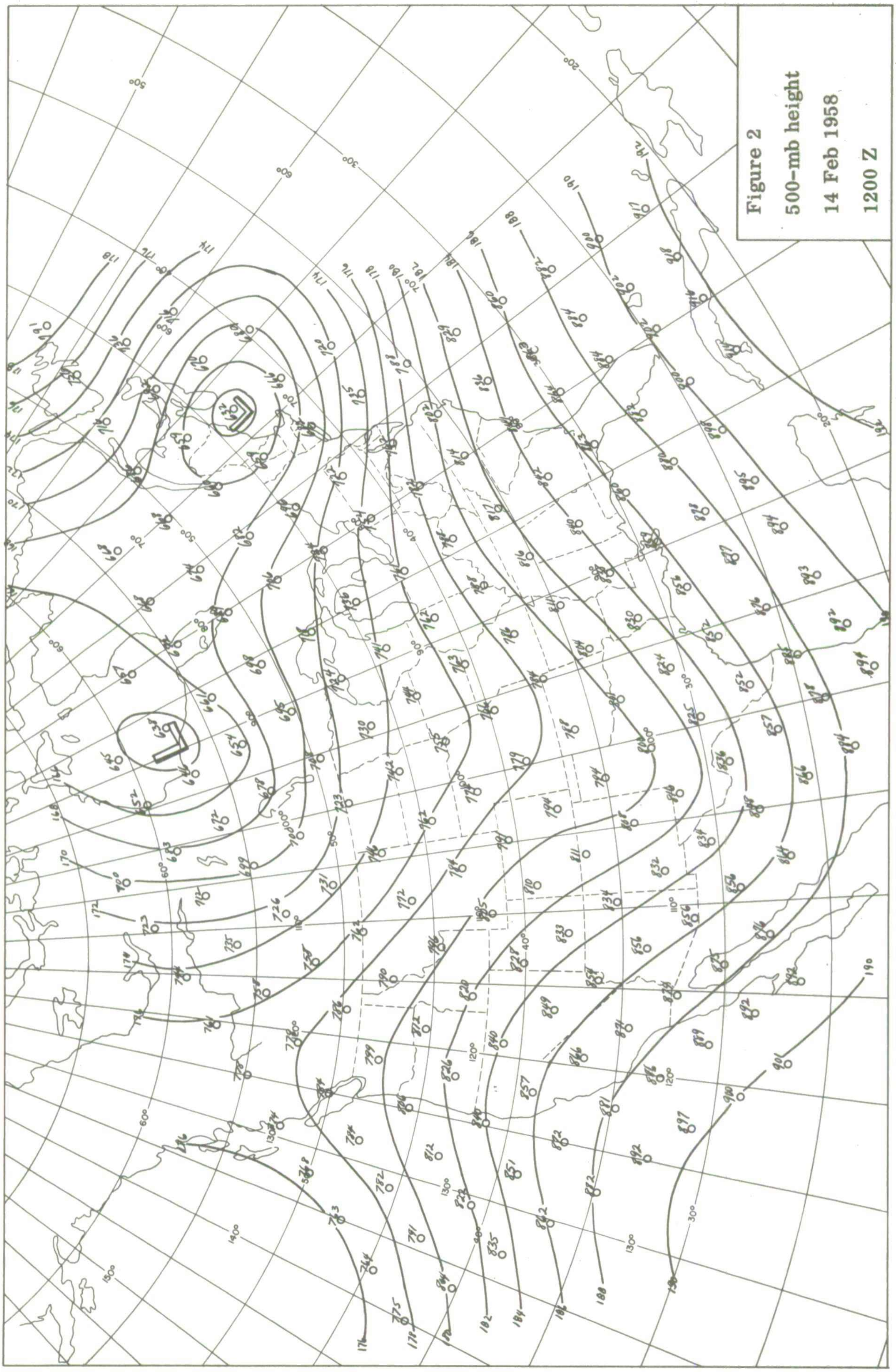


Figure 2
500-mb height
14 Feb 1958
1200 Z

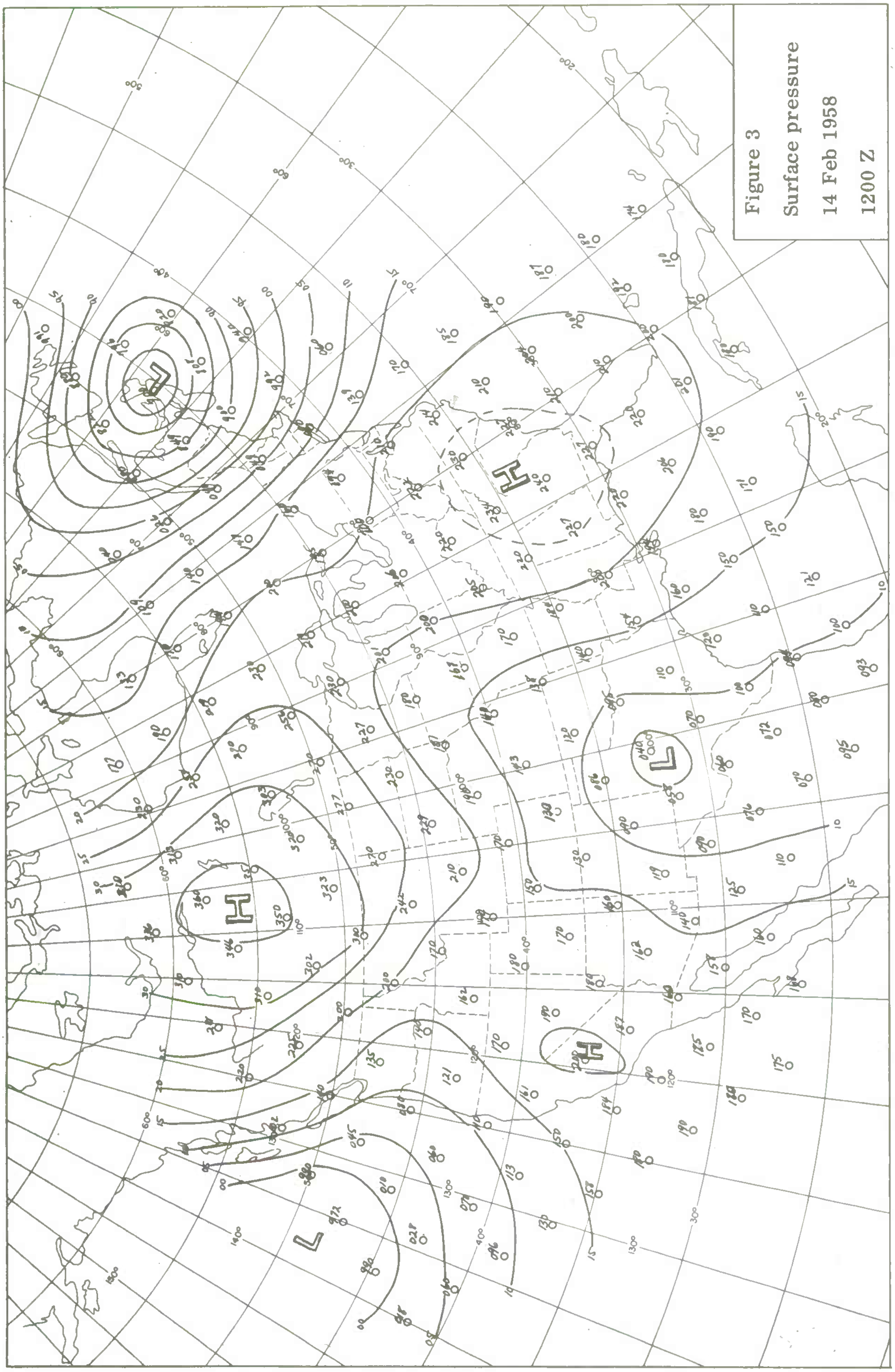


Figure 3
Surface pressure
14 Feb 1958
1200 Z

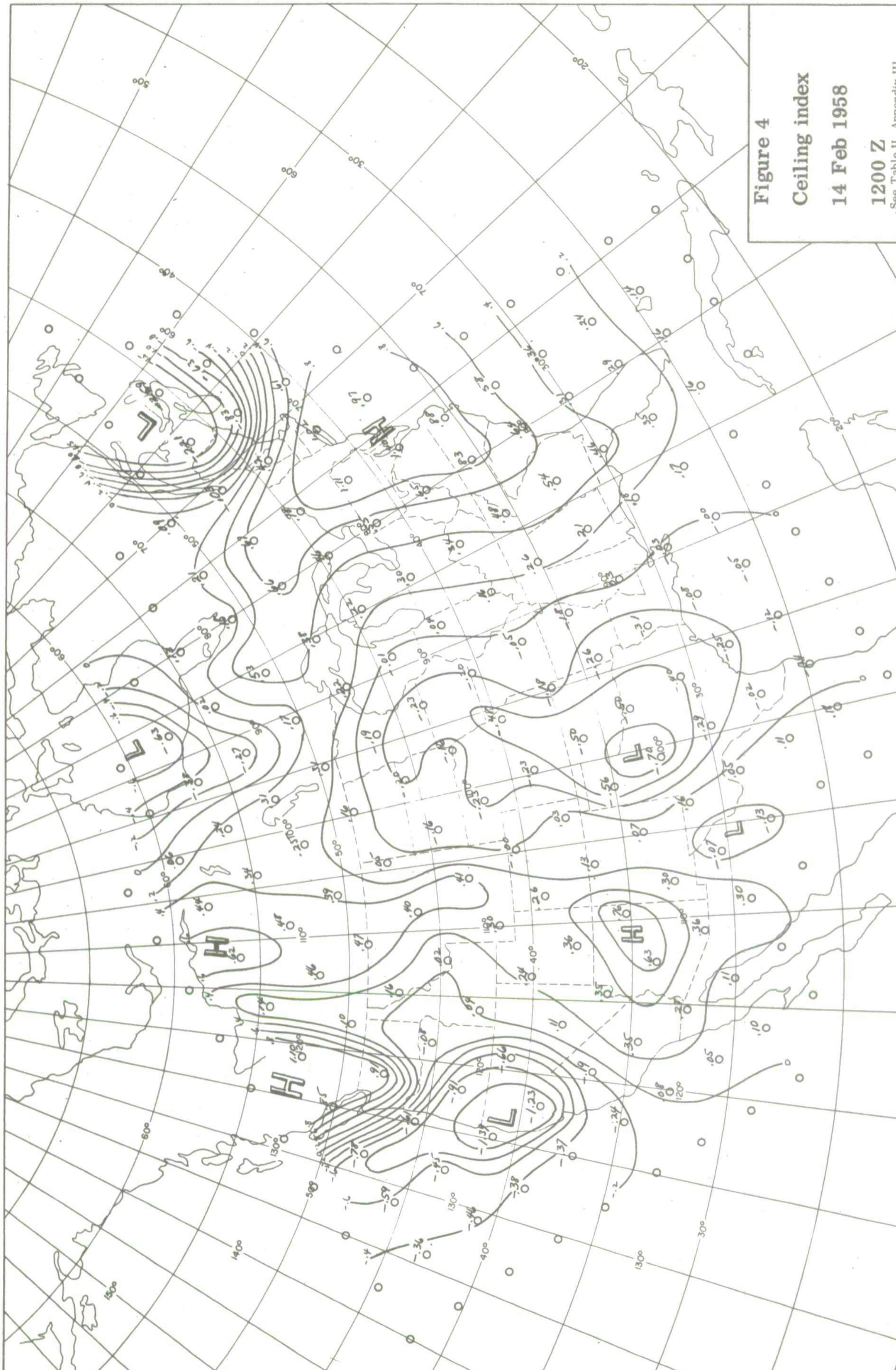


Figure 4
Ceiling index
14 Feb 1958
1200 Z
, See Table II, Appendix III

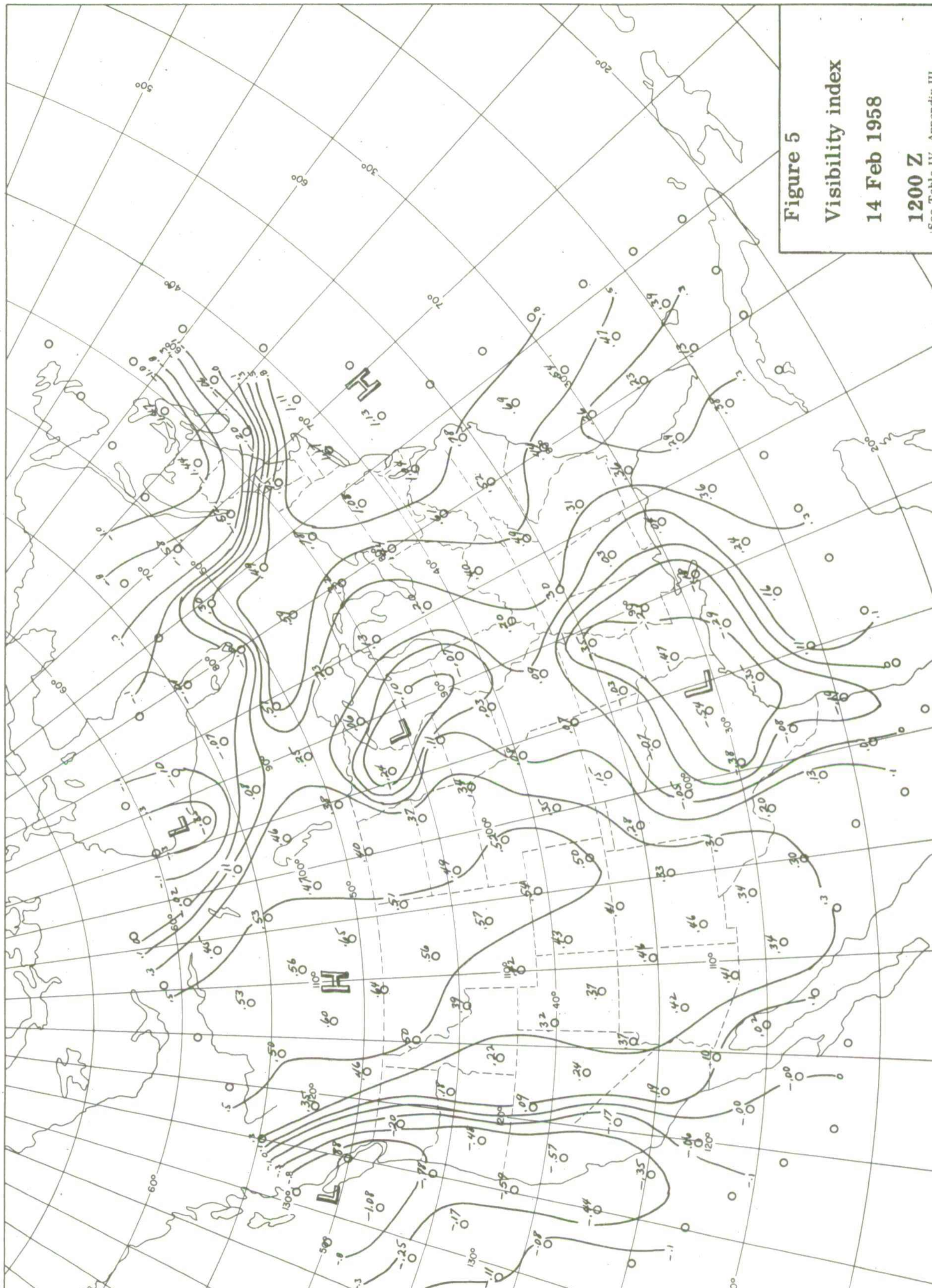


Figure 5
Visibility index
14 Feb 1958
1200 Z
(See Table IV, Appendix III)

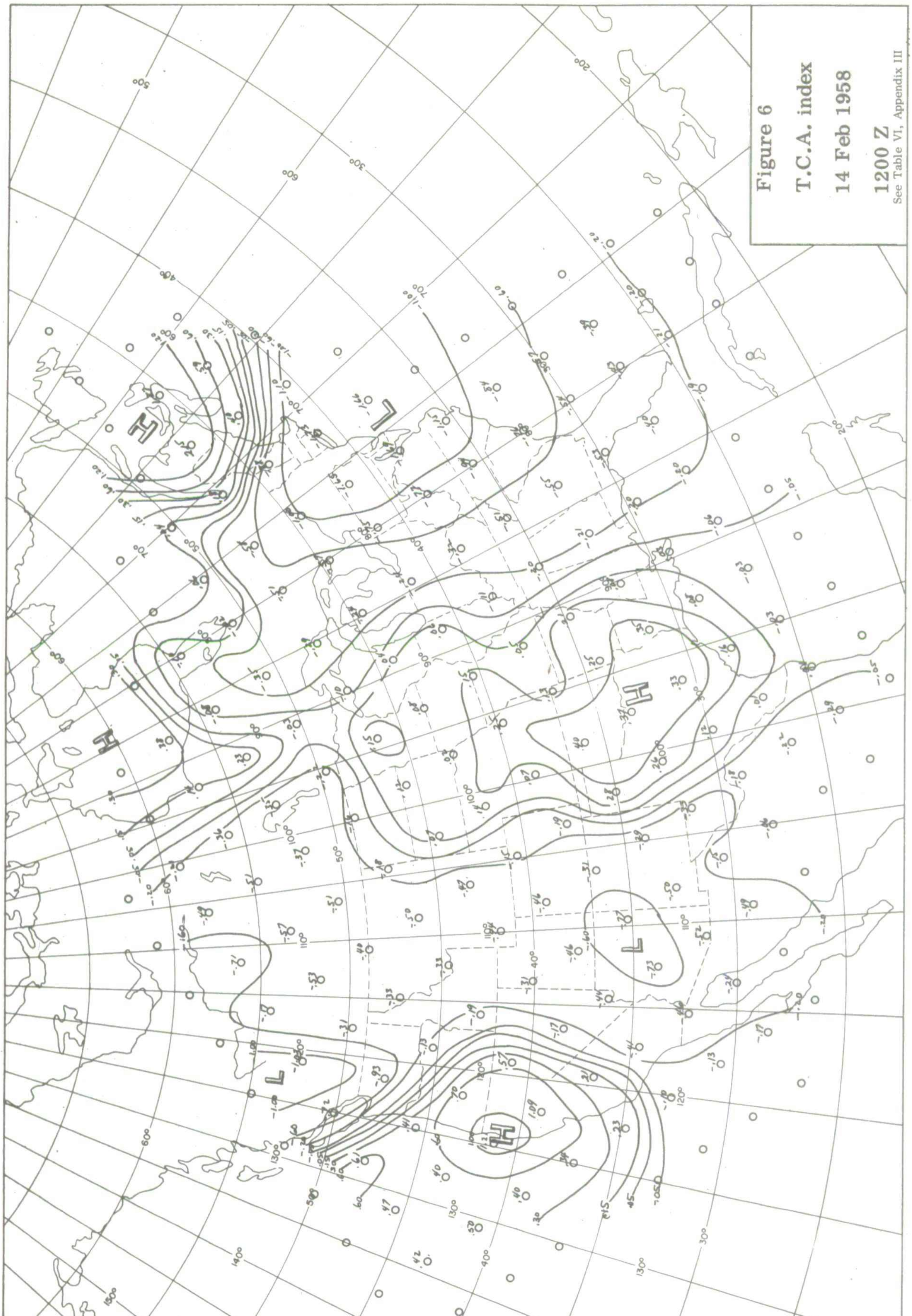


Figure 6
T.C.A. index
14 Feb 1958
1200 Z
See Table VI, Appendix III

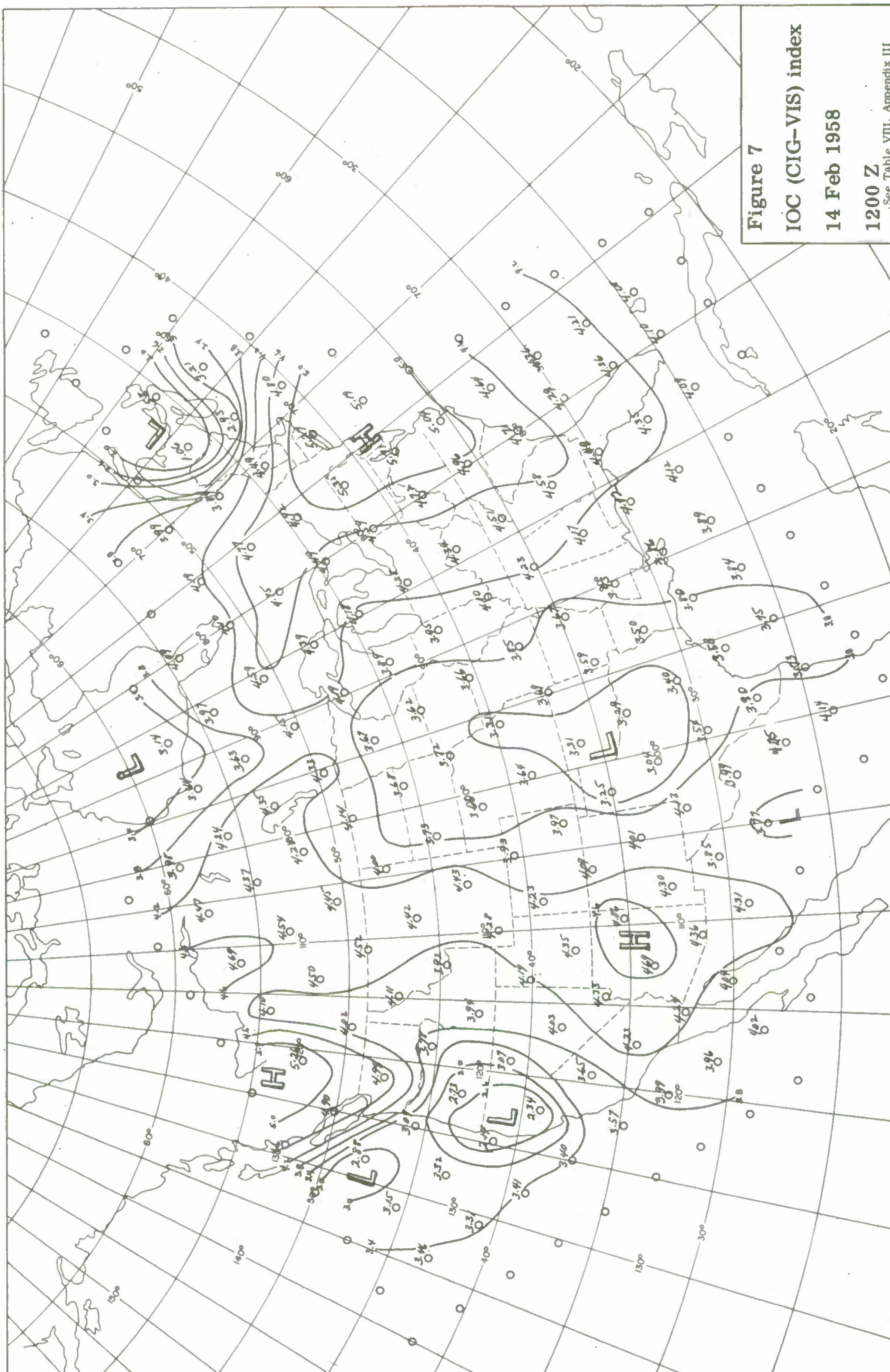


Figure 7
IOC (CIG-VIS) index
14 Feb 1958
1200 Z
See Table VIII, Appendix III

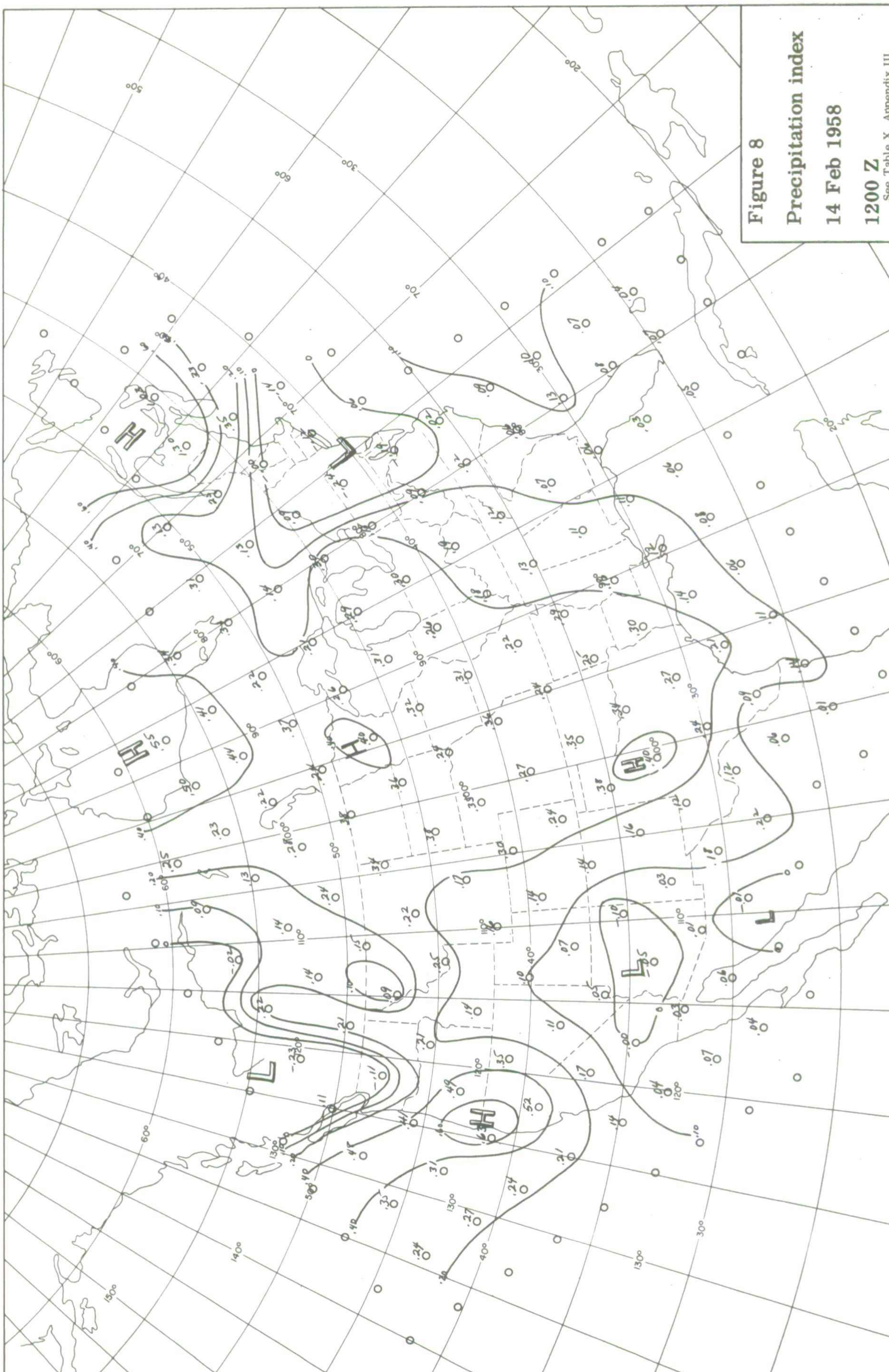


Figure 8
Precipitation index
14 Feb 1958
1200 Z
See Table X, Appendix III

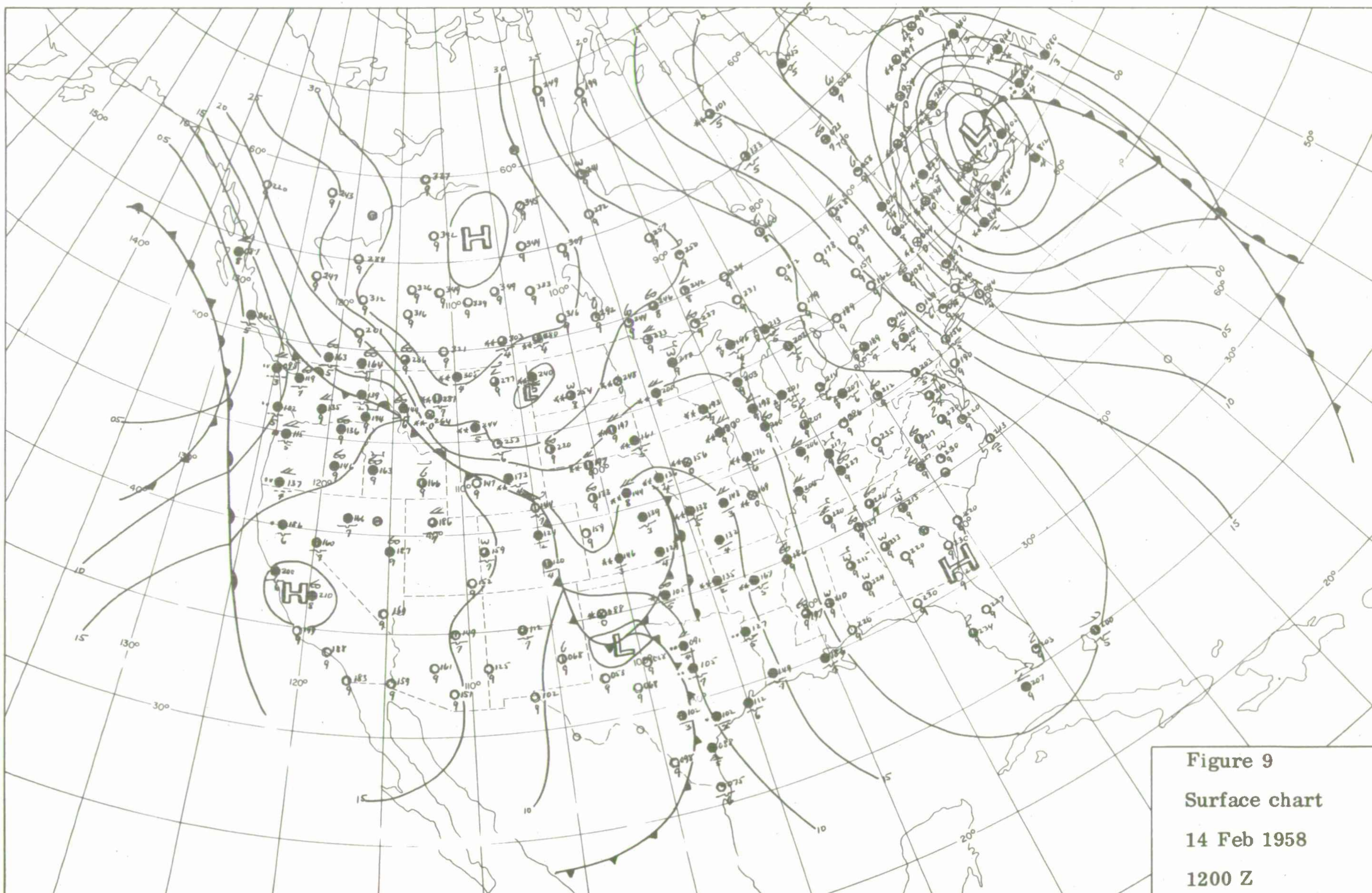


Figure 9
Surface chart
14 Feb 1958
1200 Z

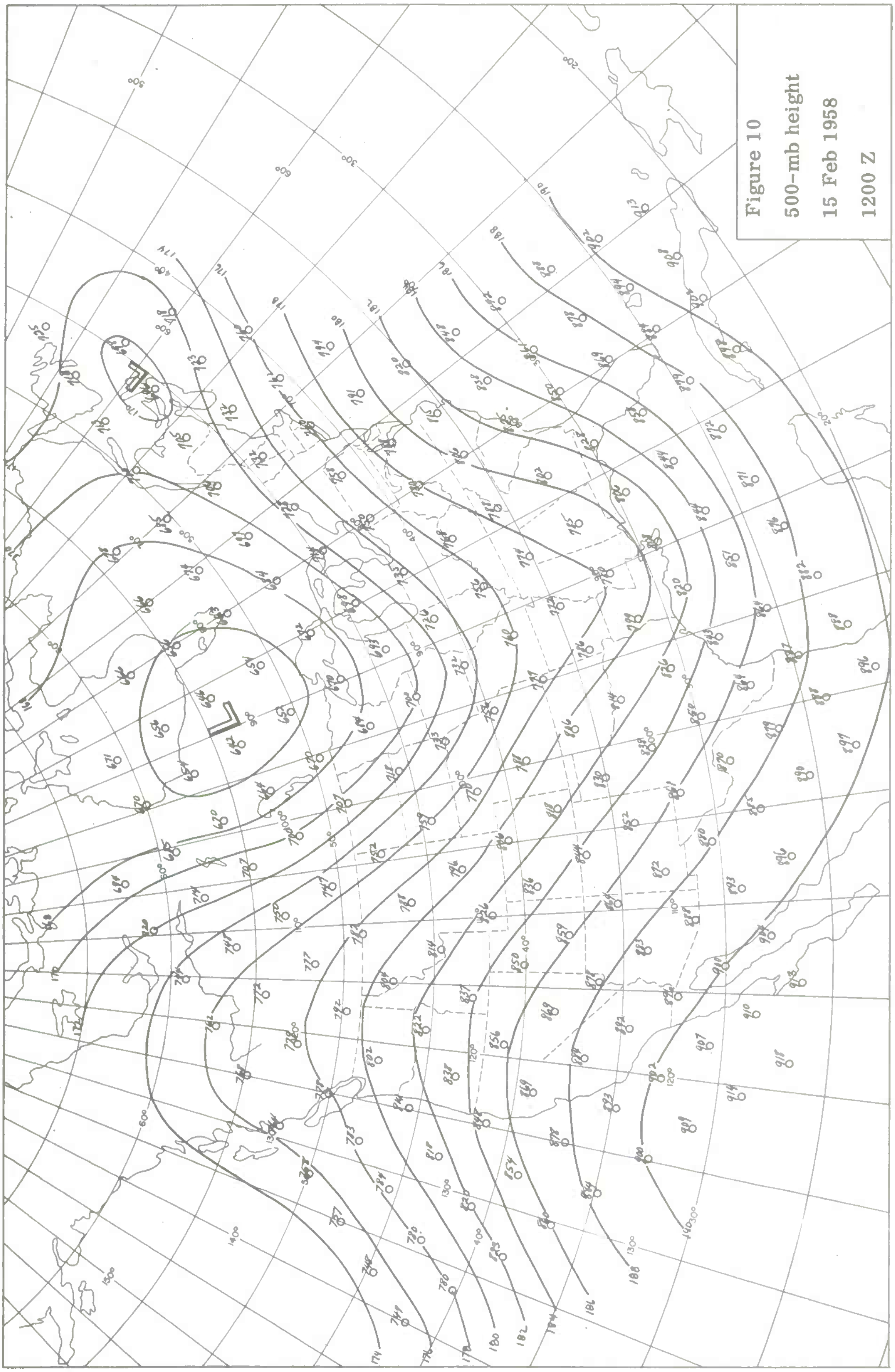


Figure 10
500-mb height
15 Feb 1958
1200 Z

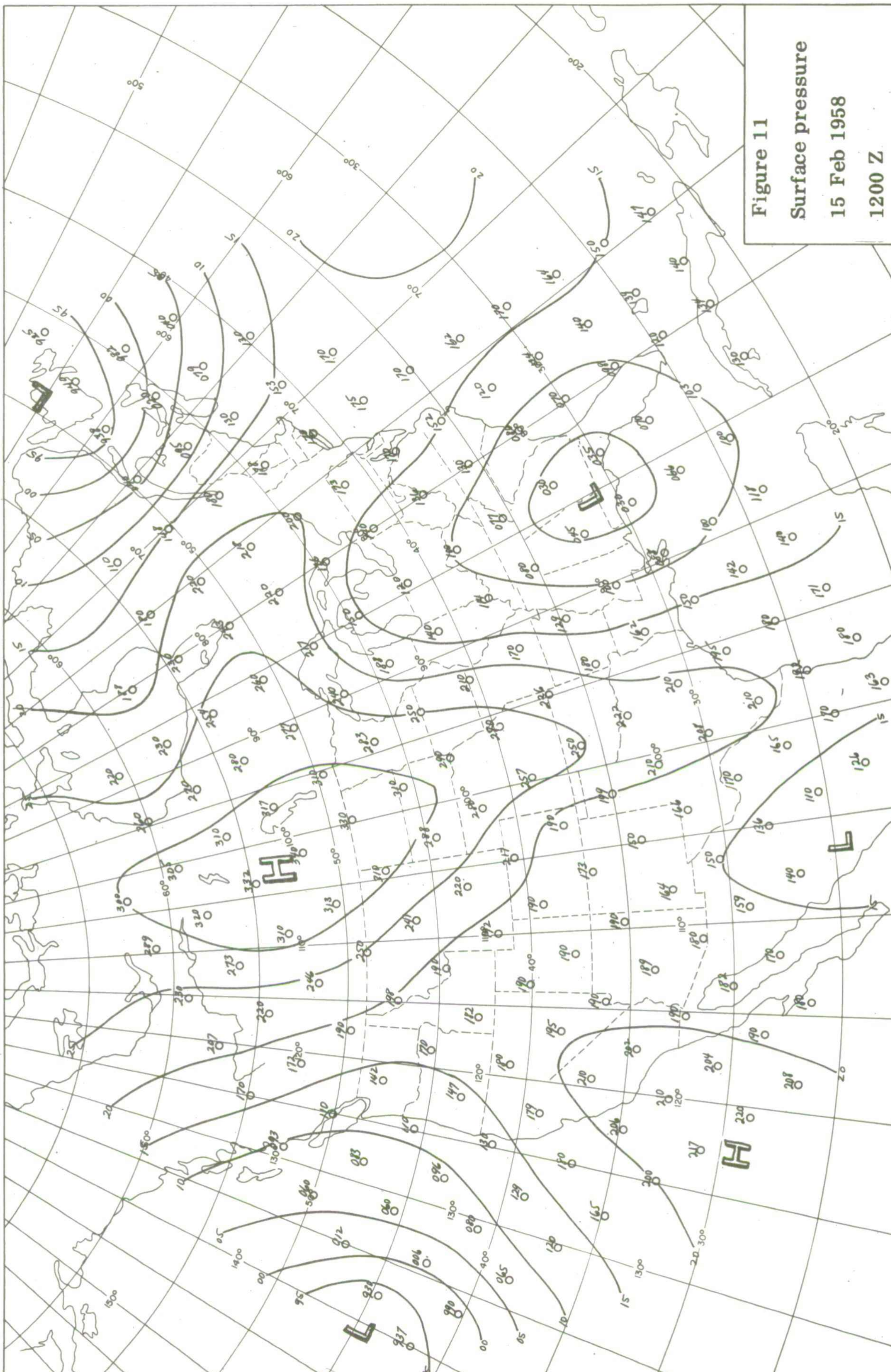


Figure 11
Surface pressure
15 Feb 1958
1200 Z

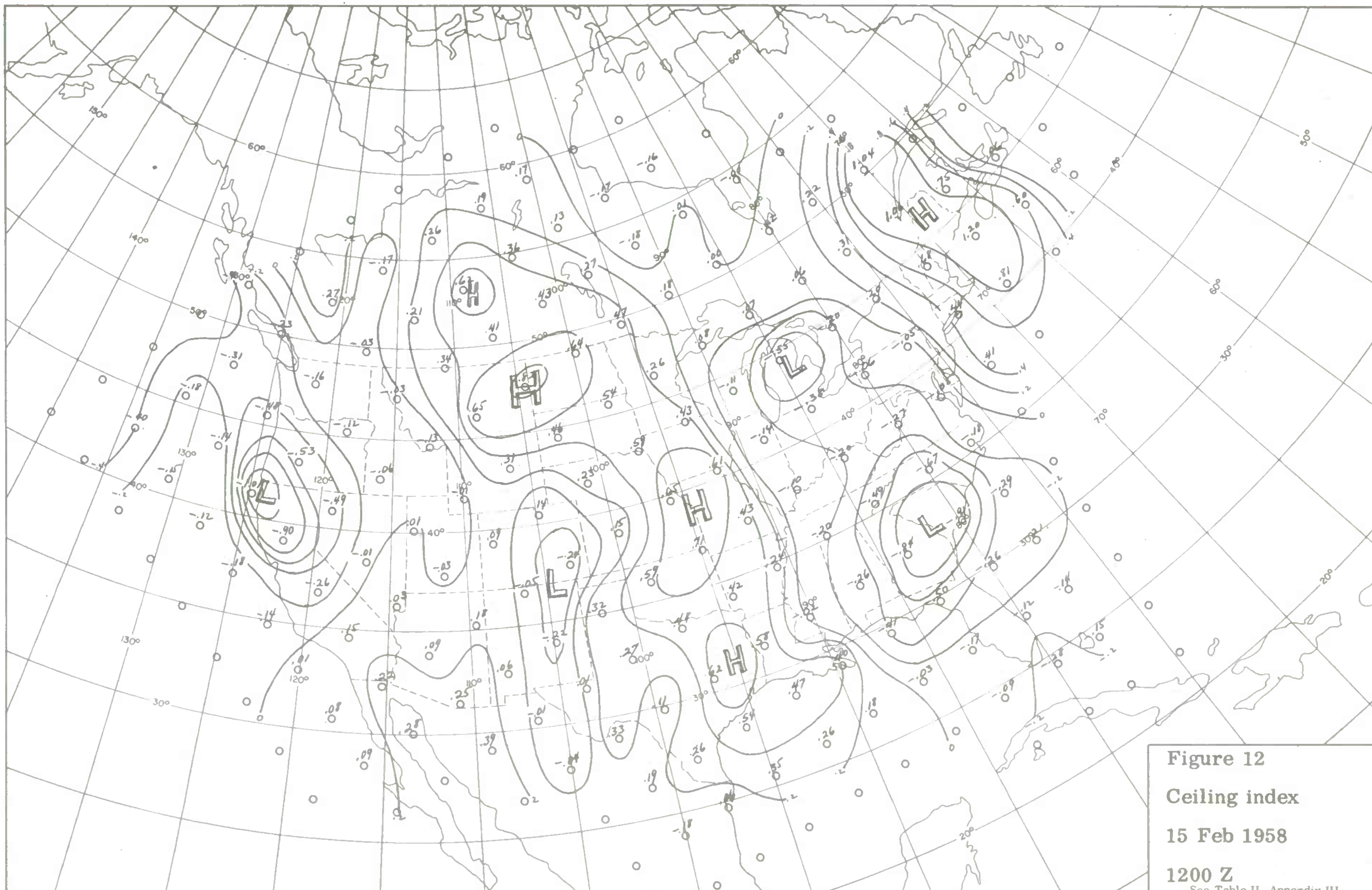


Figure 12
Ceiling index
15 Feb 1958
1200 Z
See Table II, Appendix III

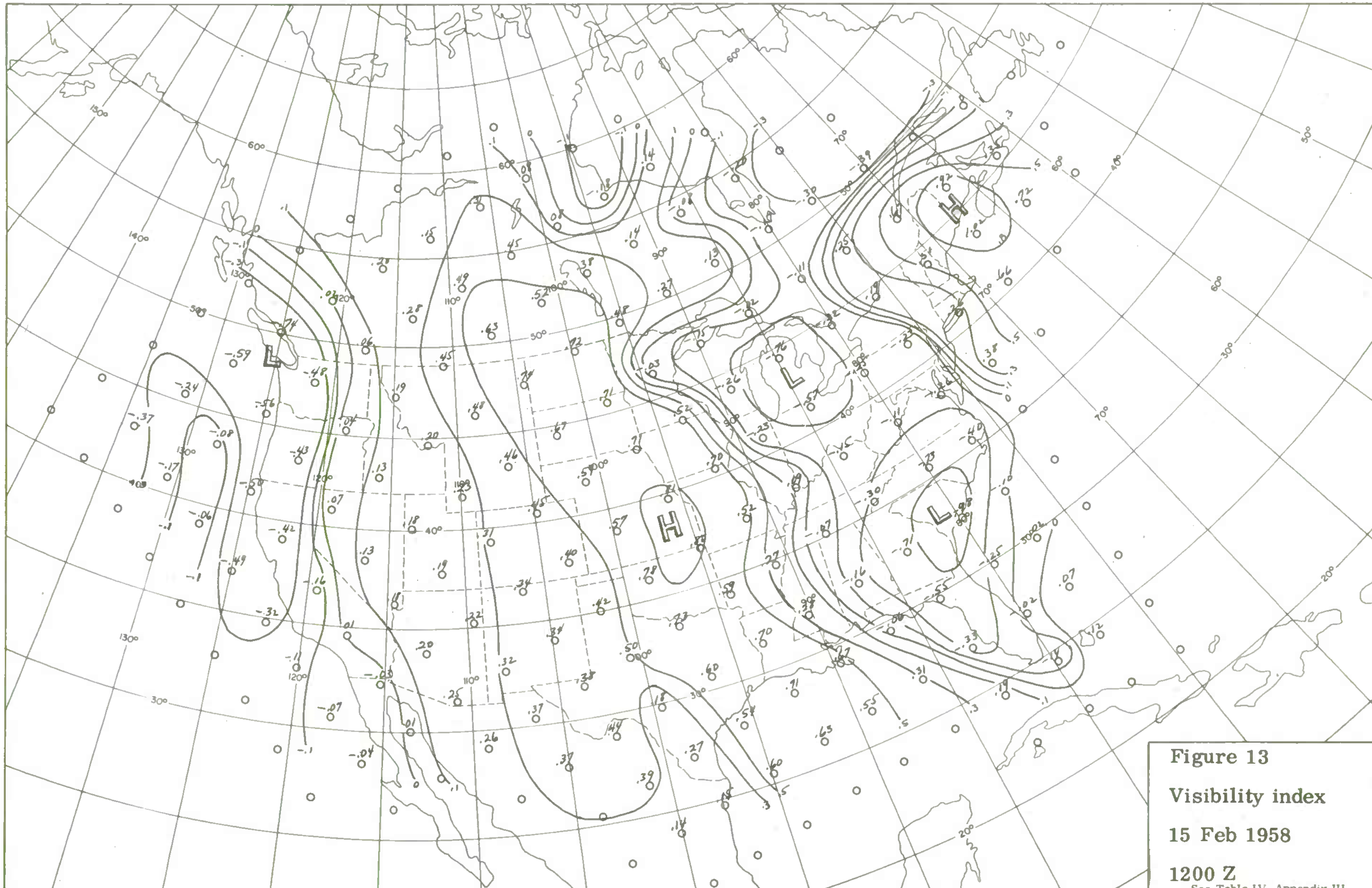


Figure 13

Visibility index

15 Feb 1958

1200 Z

(See Table IV, Appendix III

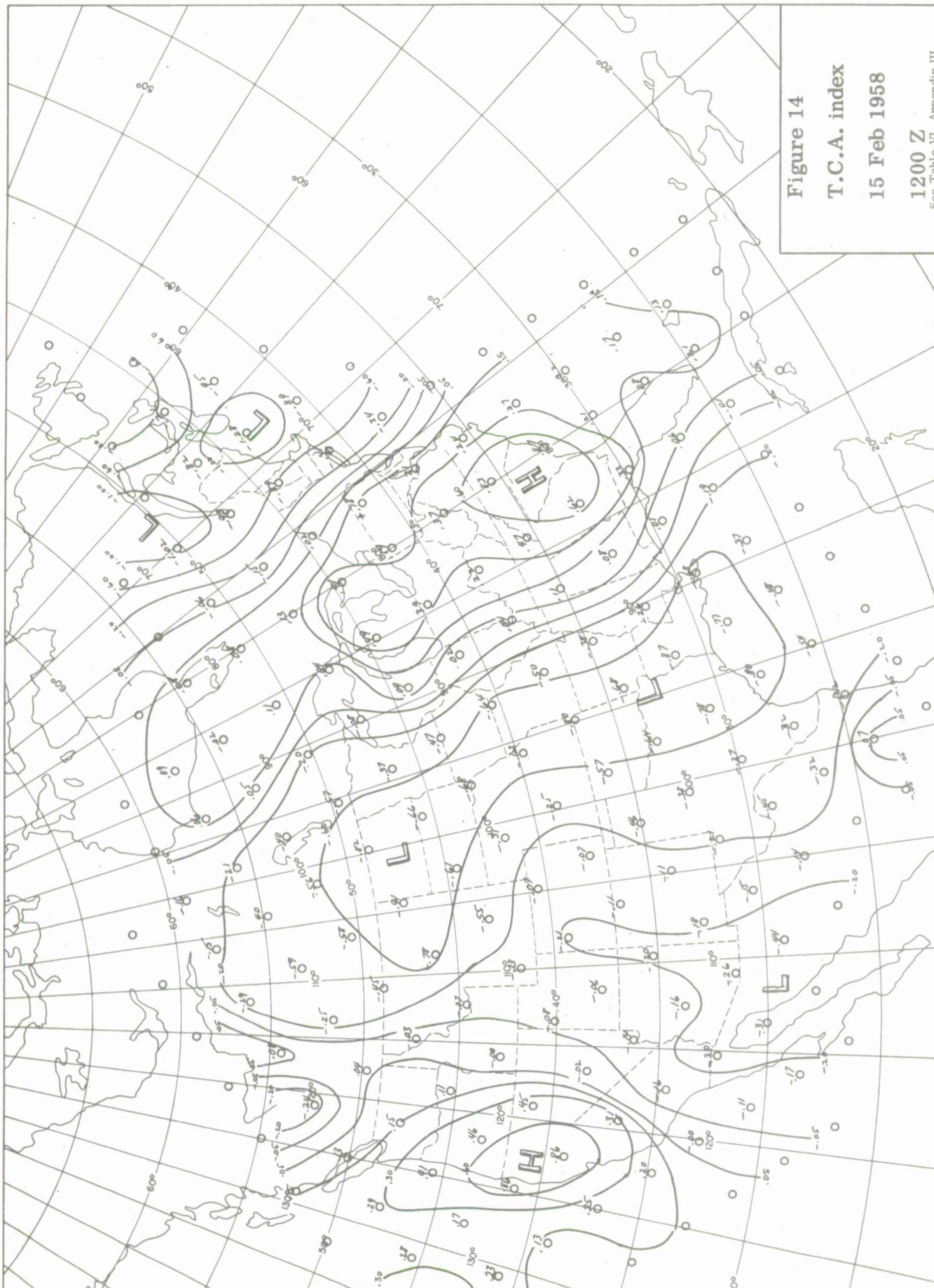


Figure 14
T.C.A. index
15 Feb 1958
1200 Z
See Table VI, Appendix III

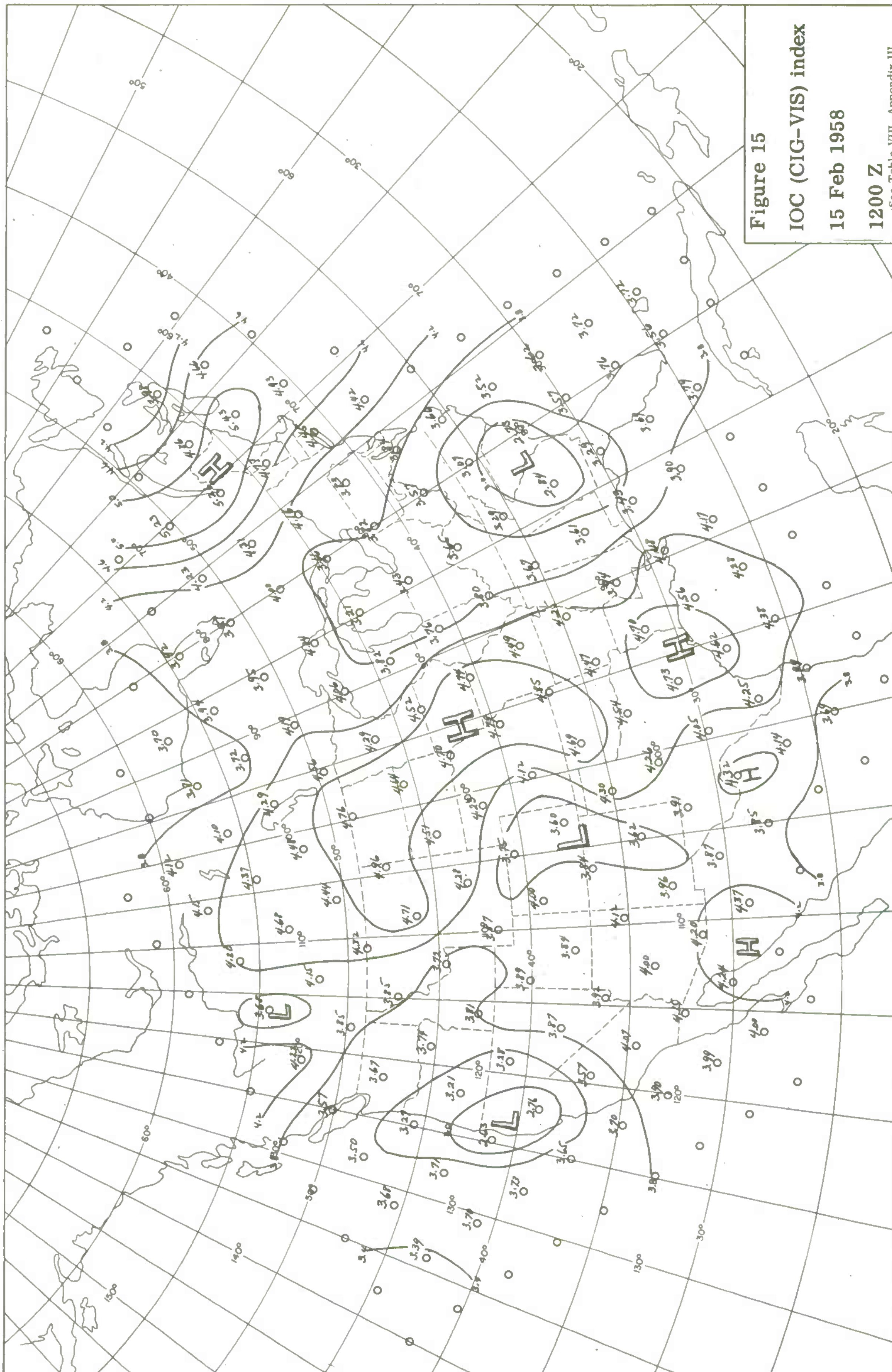


Figure 15
IOC (CIG–VIS) index
15 Feb 1958
1200 Z
[1]See Table VIII, Appendix III

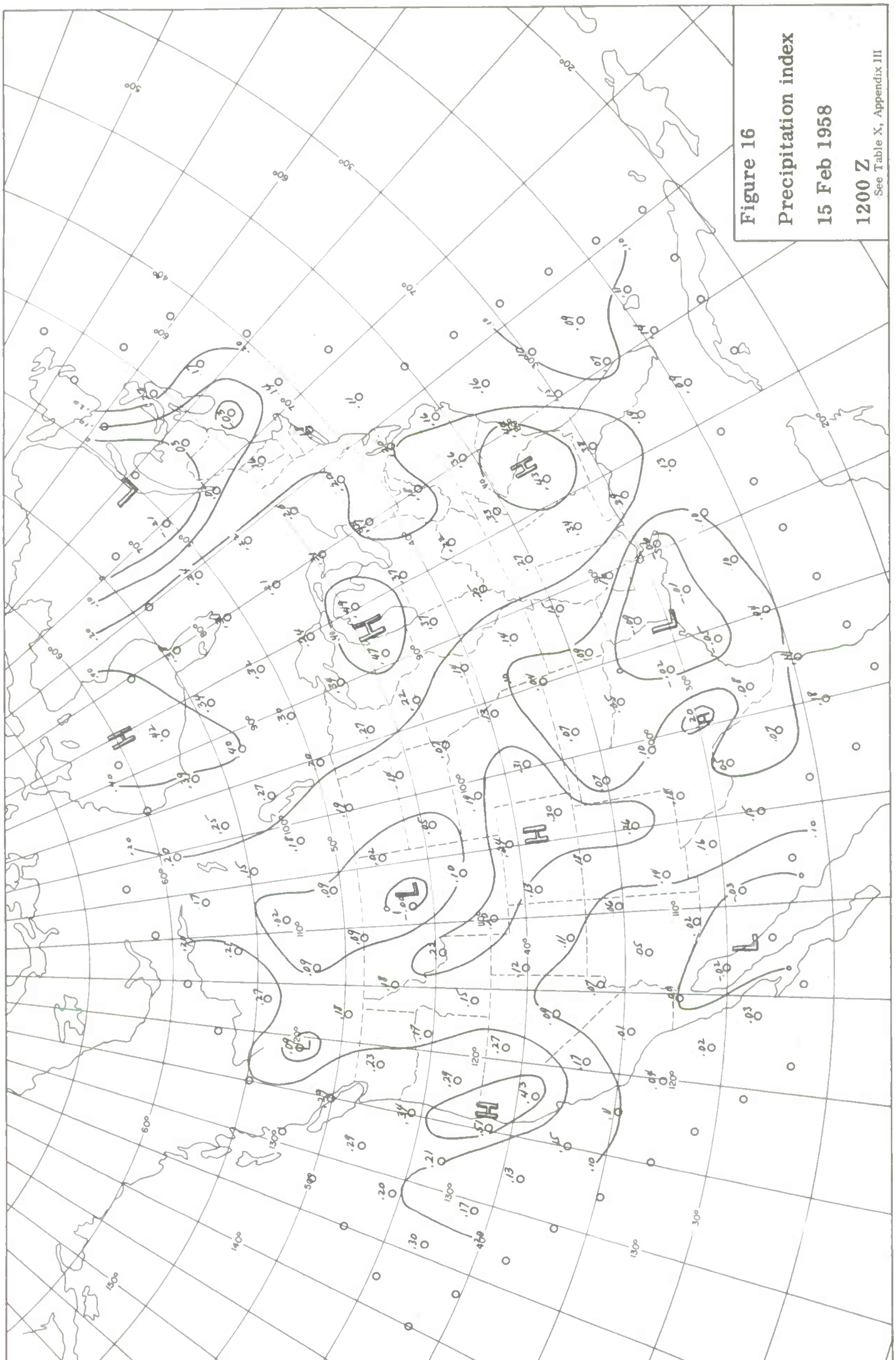


Figure 16
Precipitation index
15 Feb 1958
1200 Z
See Table X, Appendix III

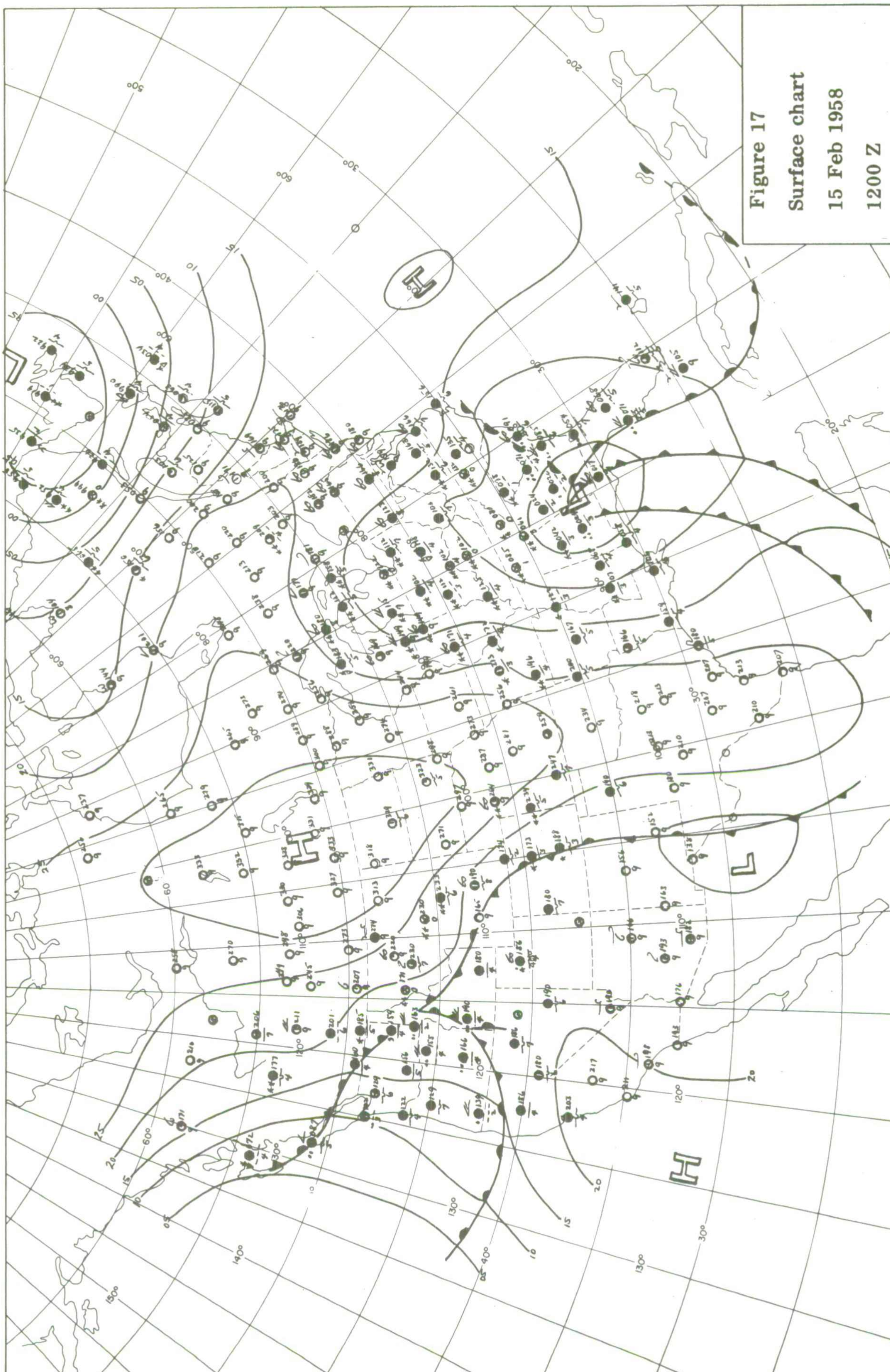


Figure 17
Surface chart
15 Feb 1958
1200 Z

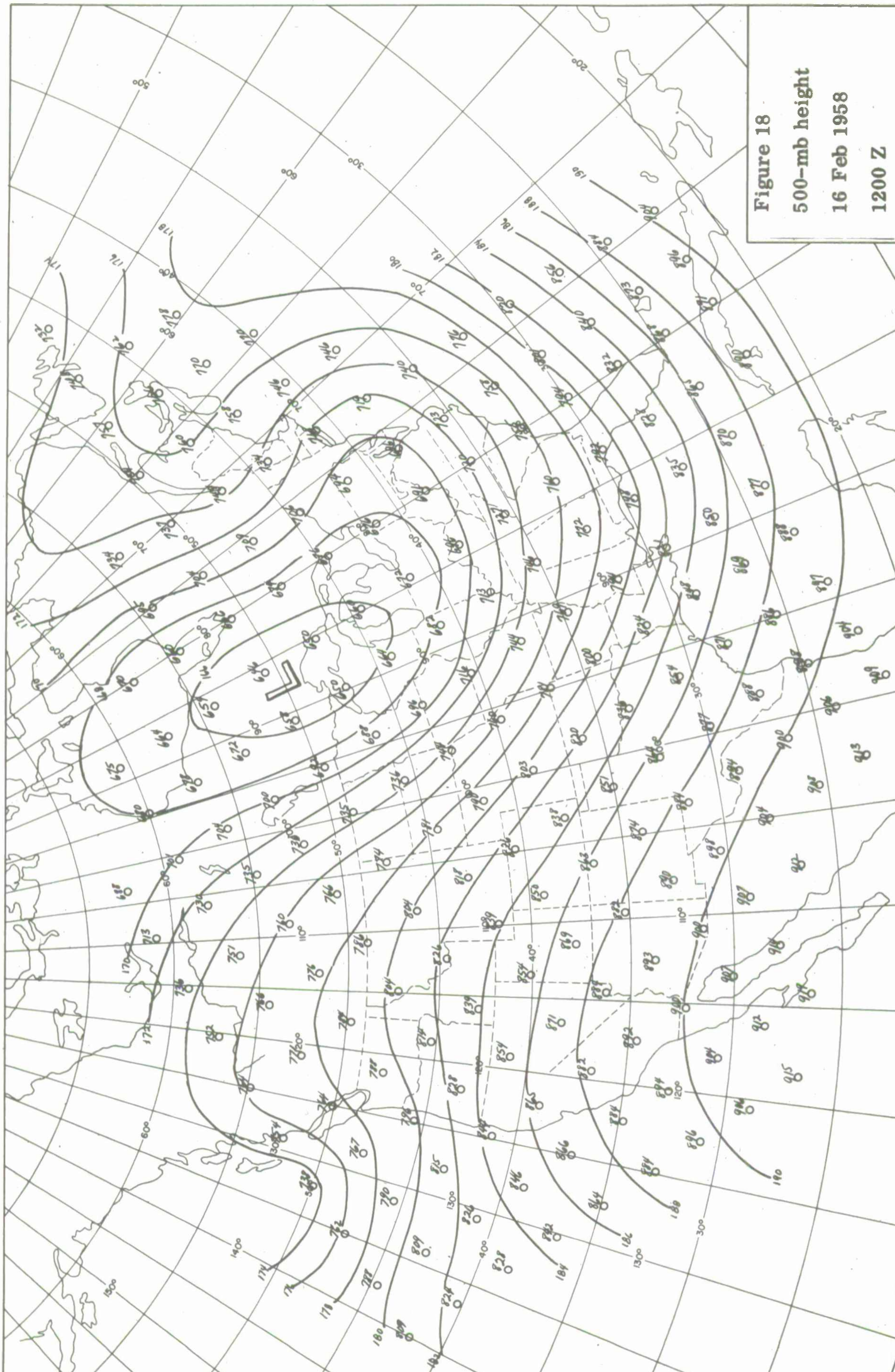


Figure 18
500–mb height
16 Feb 1958
1200 Z

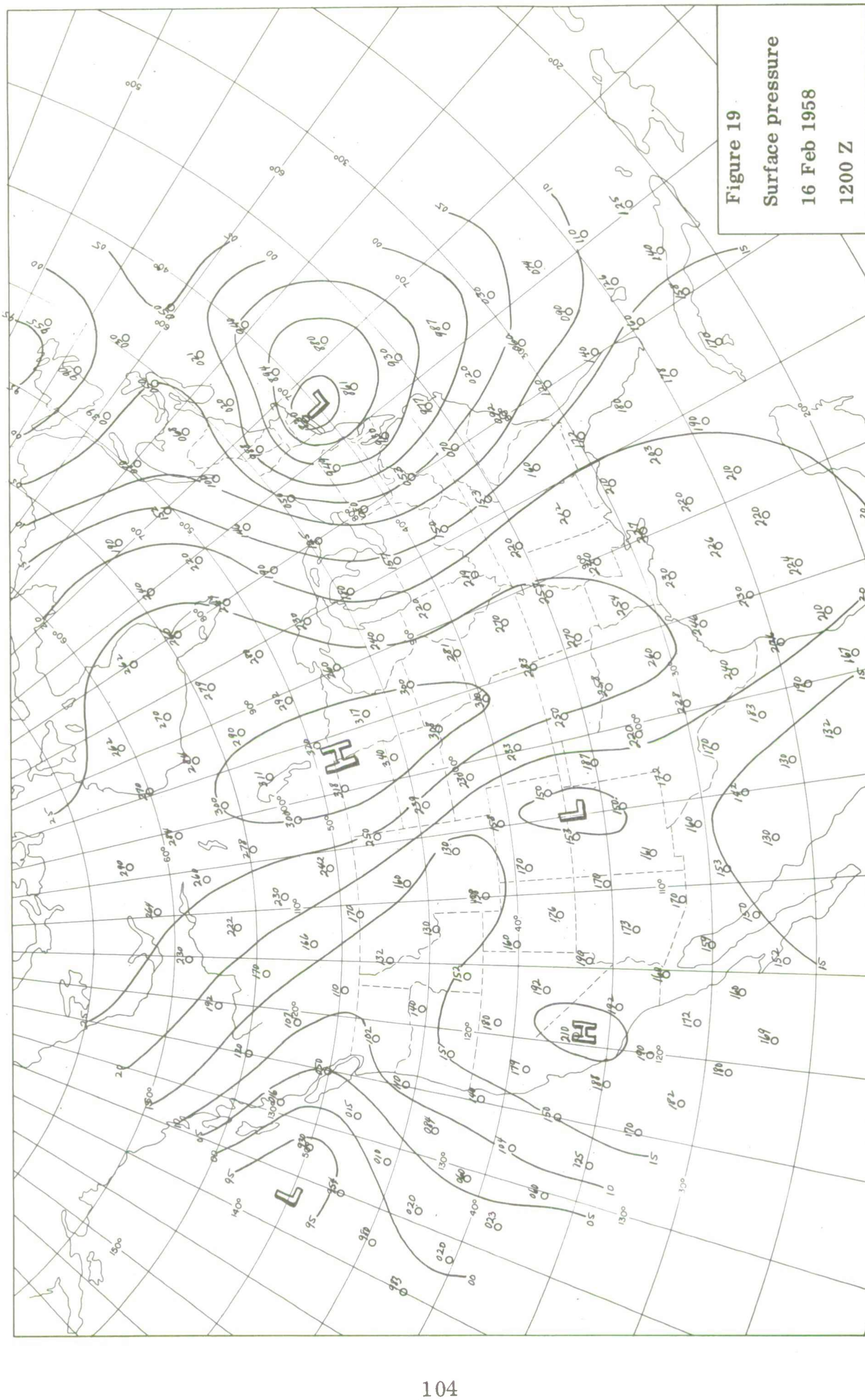


Figure 19
Surface pressure
16 Feb 1958
1200 Z

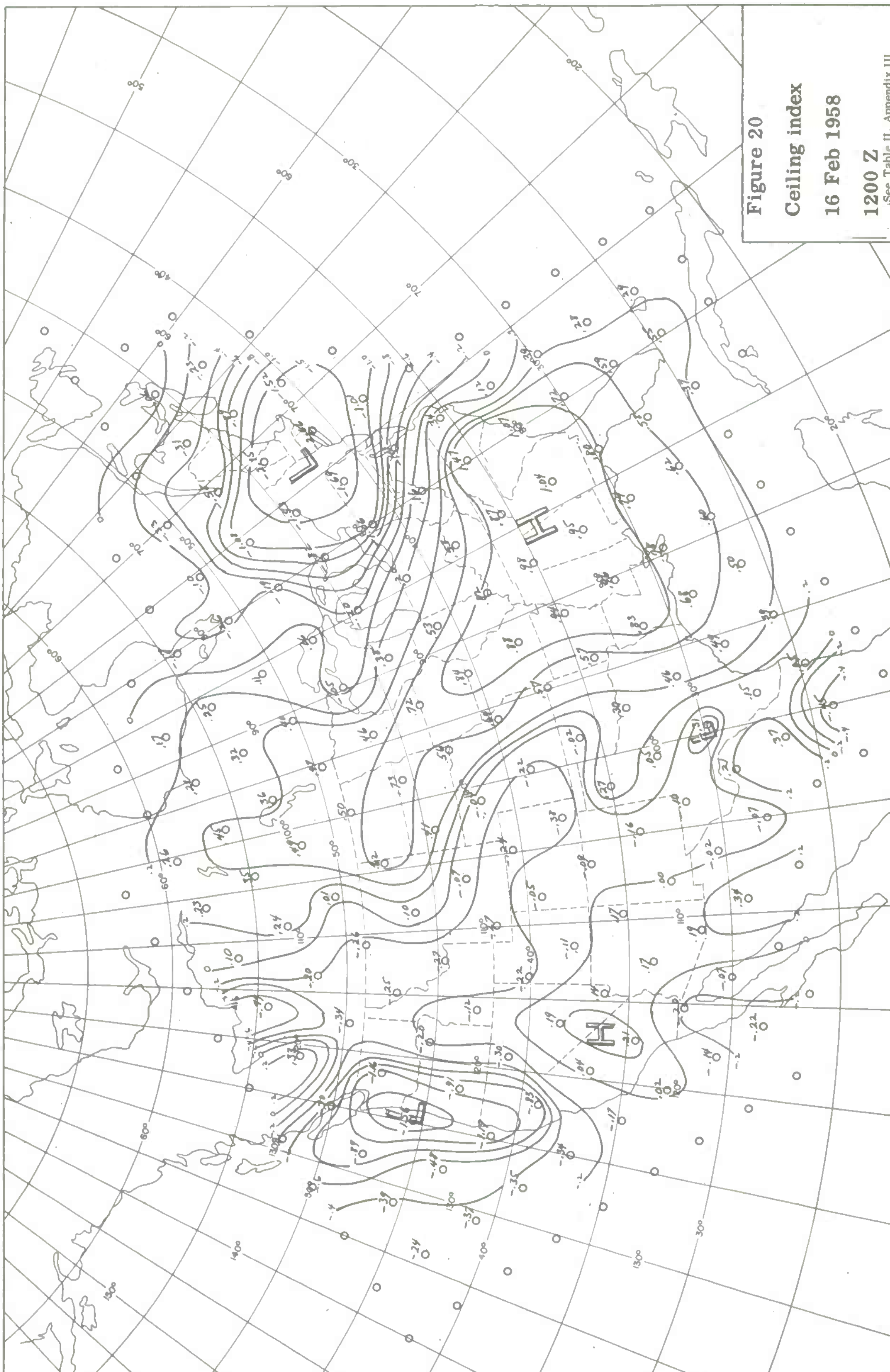


Figure 20
Ceiling index
16 Feb 1958
1200 Z
(See Table II, Appendix III)

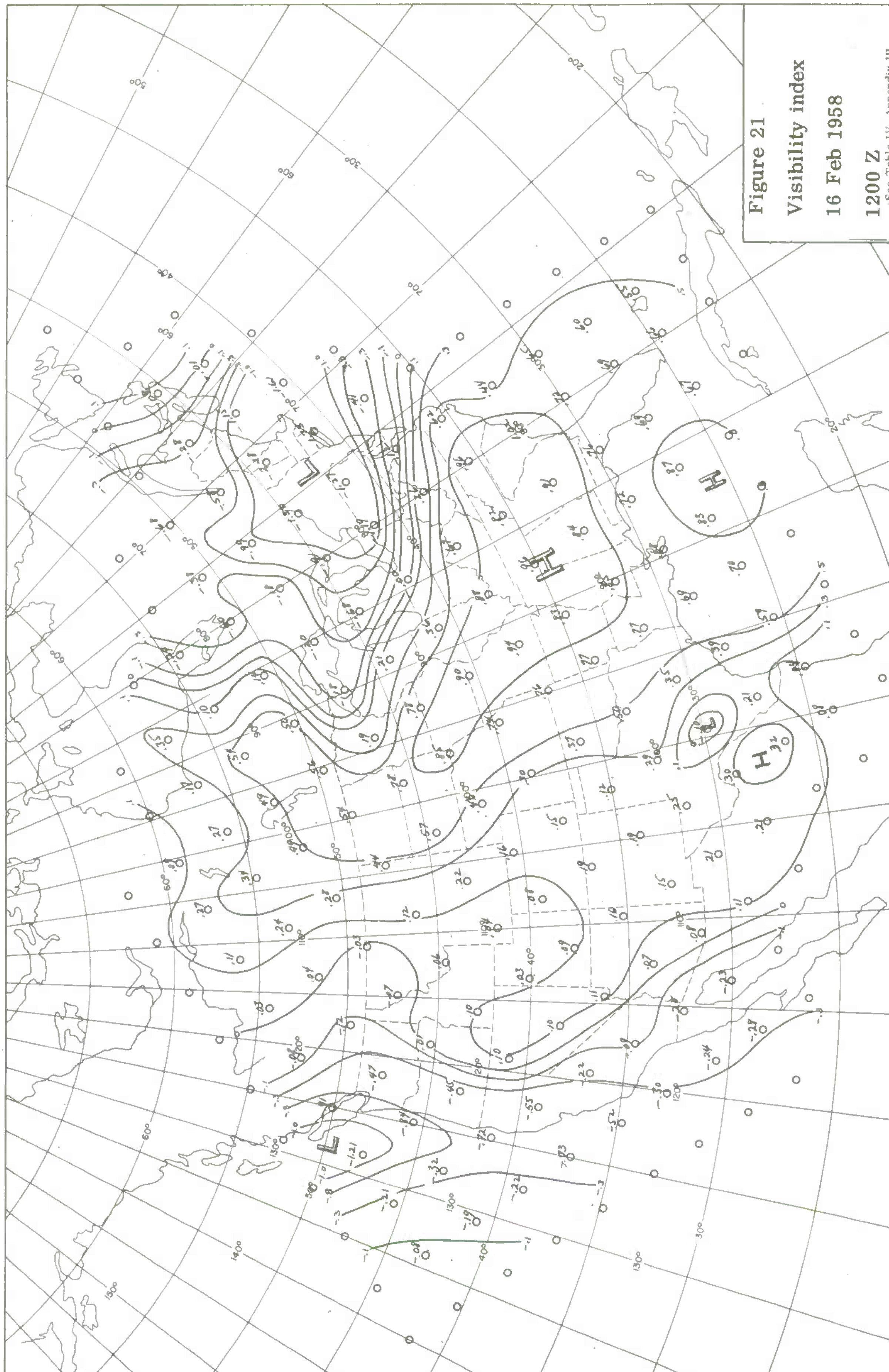


Figure 21

Visibility index

16 Feb 1958

1200 Z

(See Table IV, Appendix III

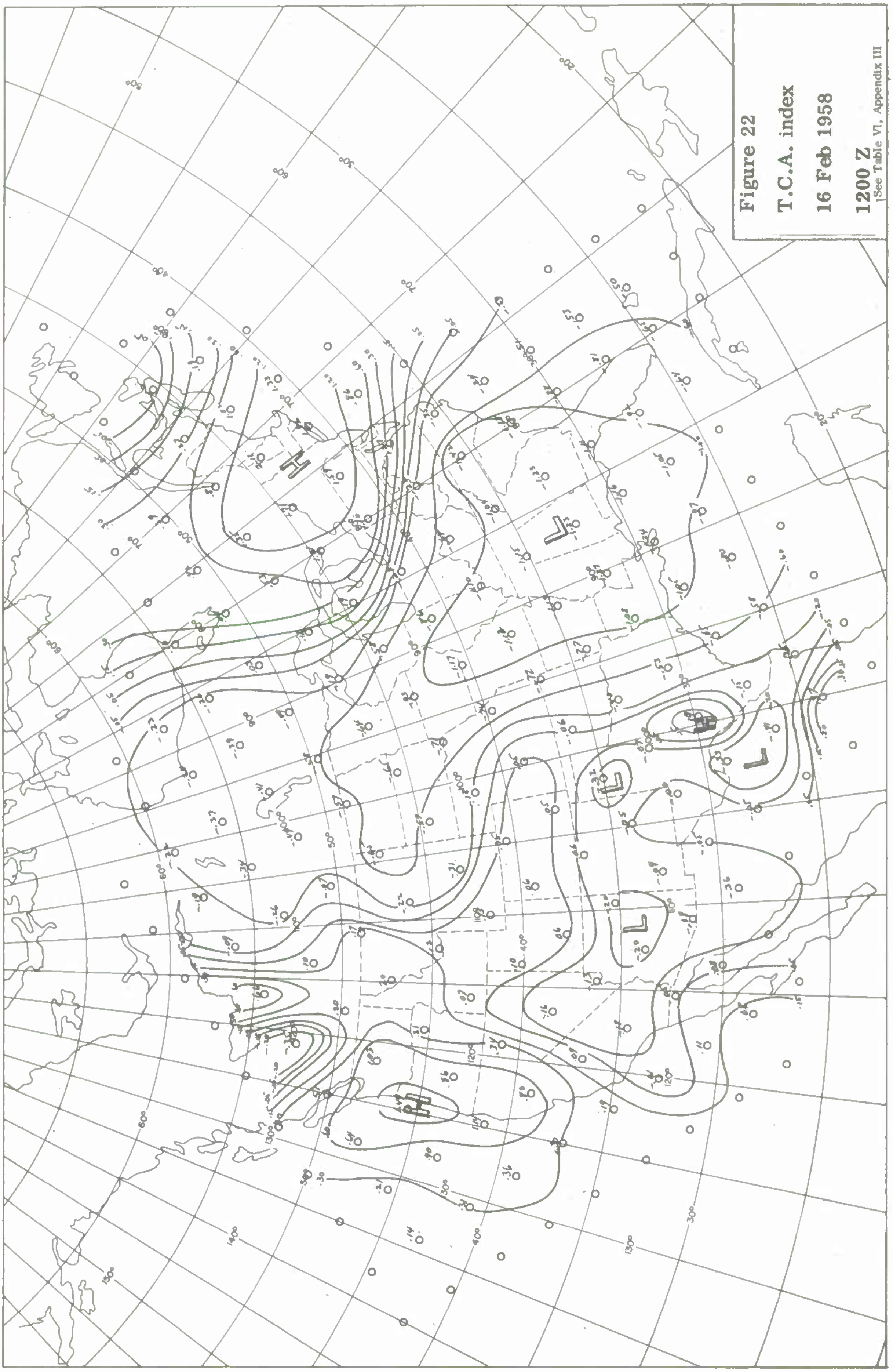


Figure 22
T.C.A. index
16 Feb 1958
1200 Z
(See Table VI, Appendix III

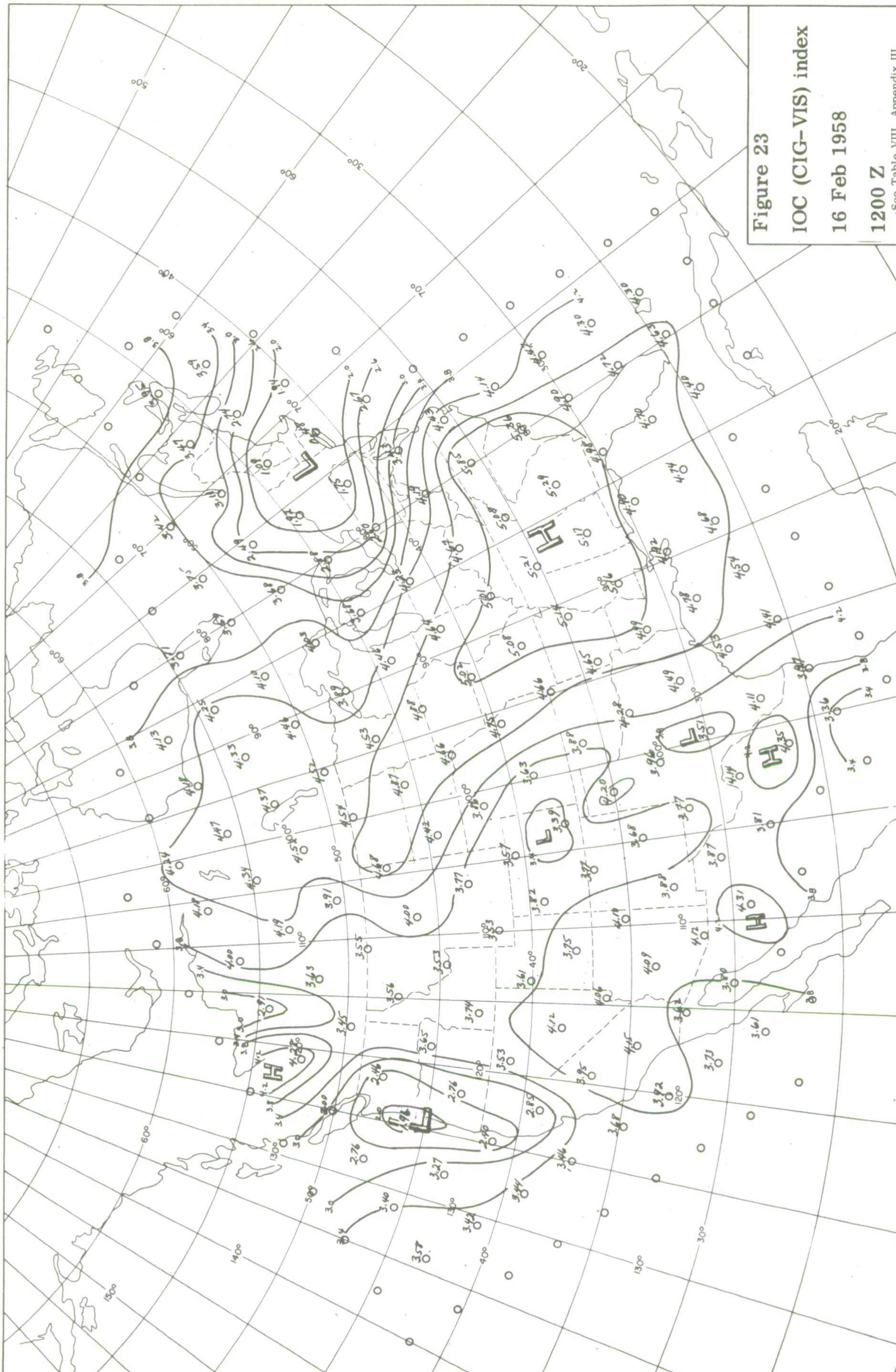


Figure 23
IOC (CIG–VIS) index
16 Feb 1958
1200 Z
See Table VIII, Appendix III

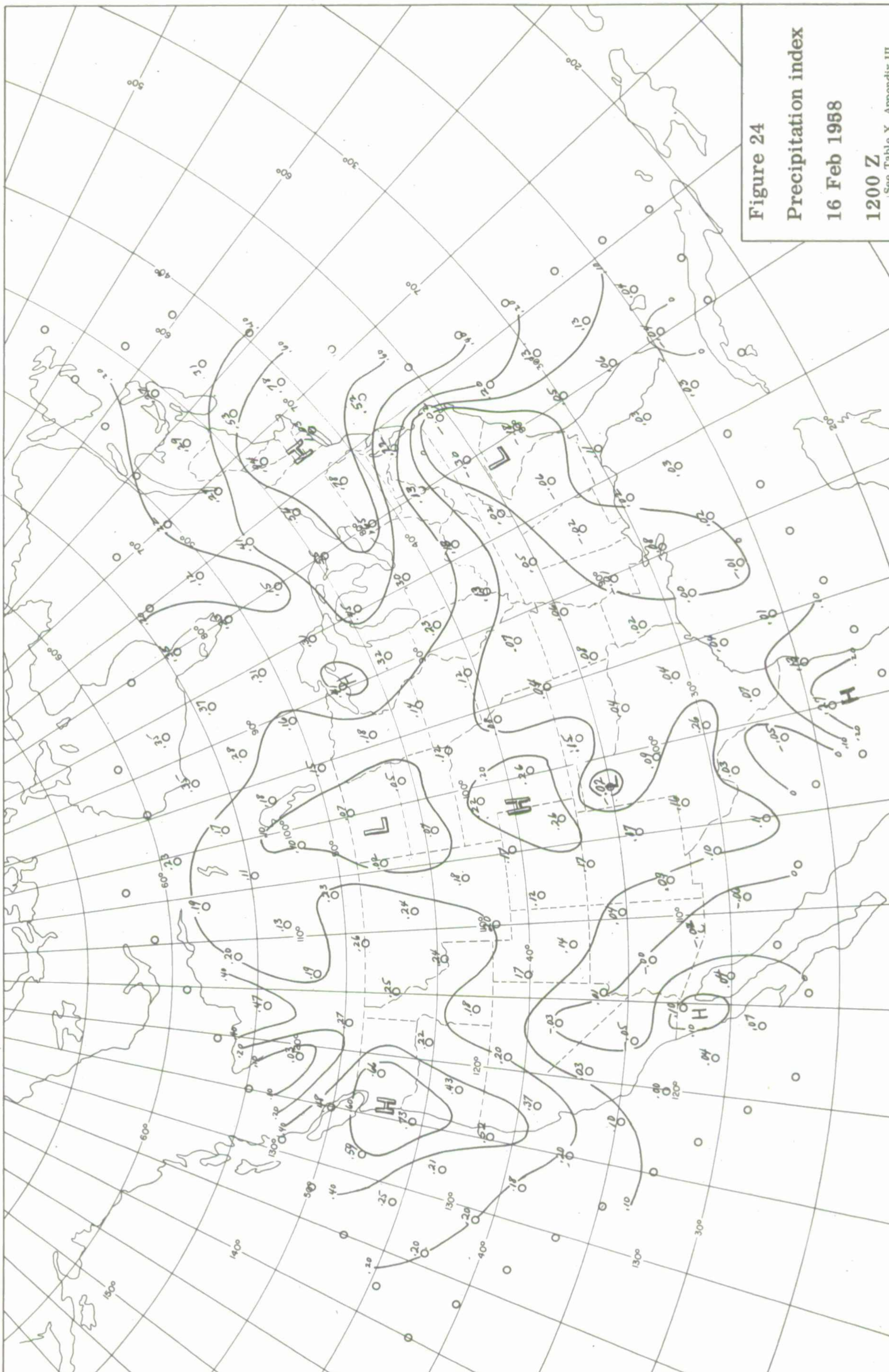


Figure 24
Precipitation index
16 Feb 1958
1200 Z
(See Table X, Appendix III

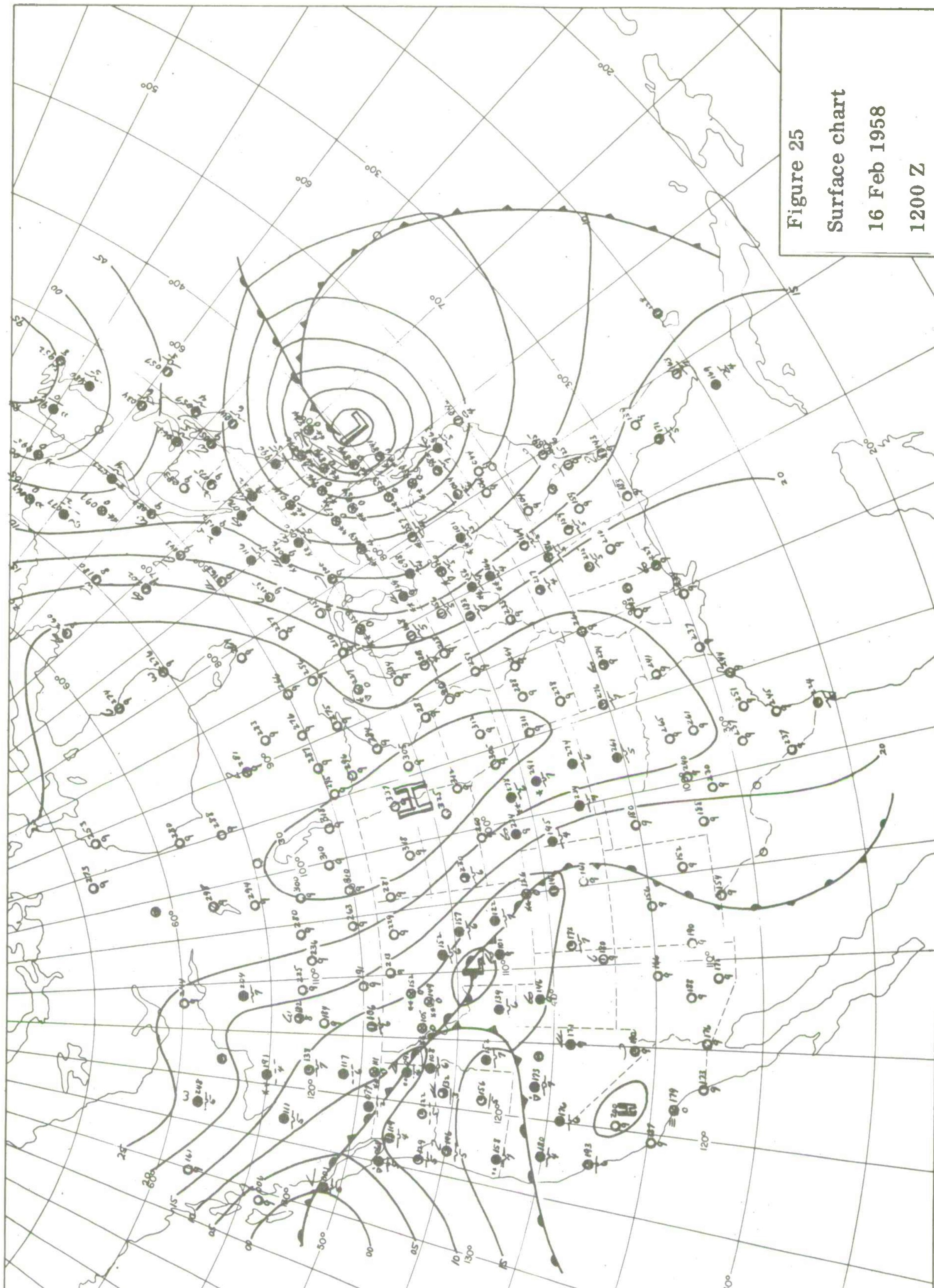


Figure 25
Surface chart
16 Feb 1958
1200 Z

APPENDIX V

SYNOPTIC MAPS, AUGUST

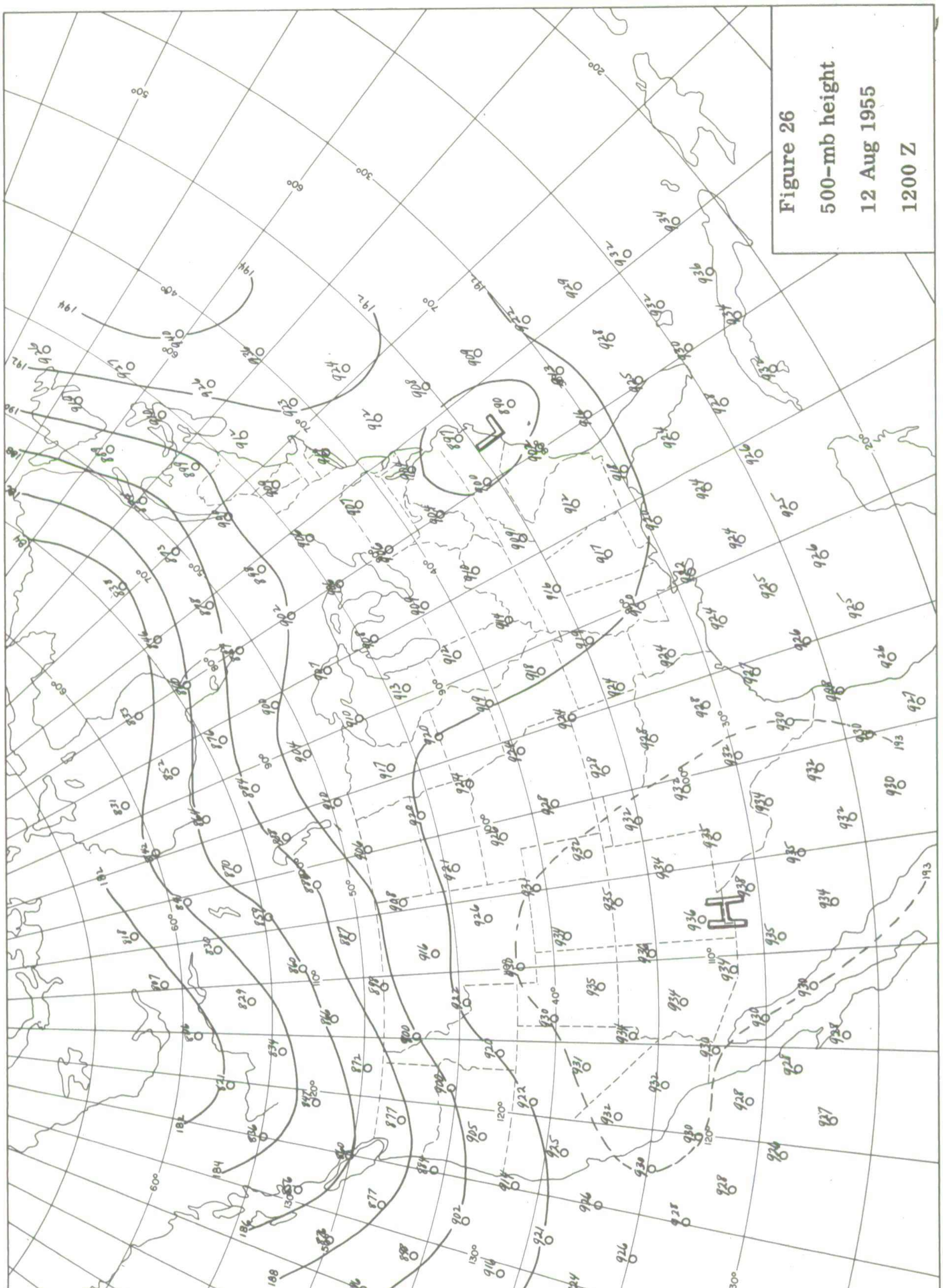


Figure 26
500–mb height
12 Aug 1955
1200 Z

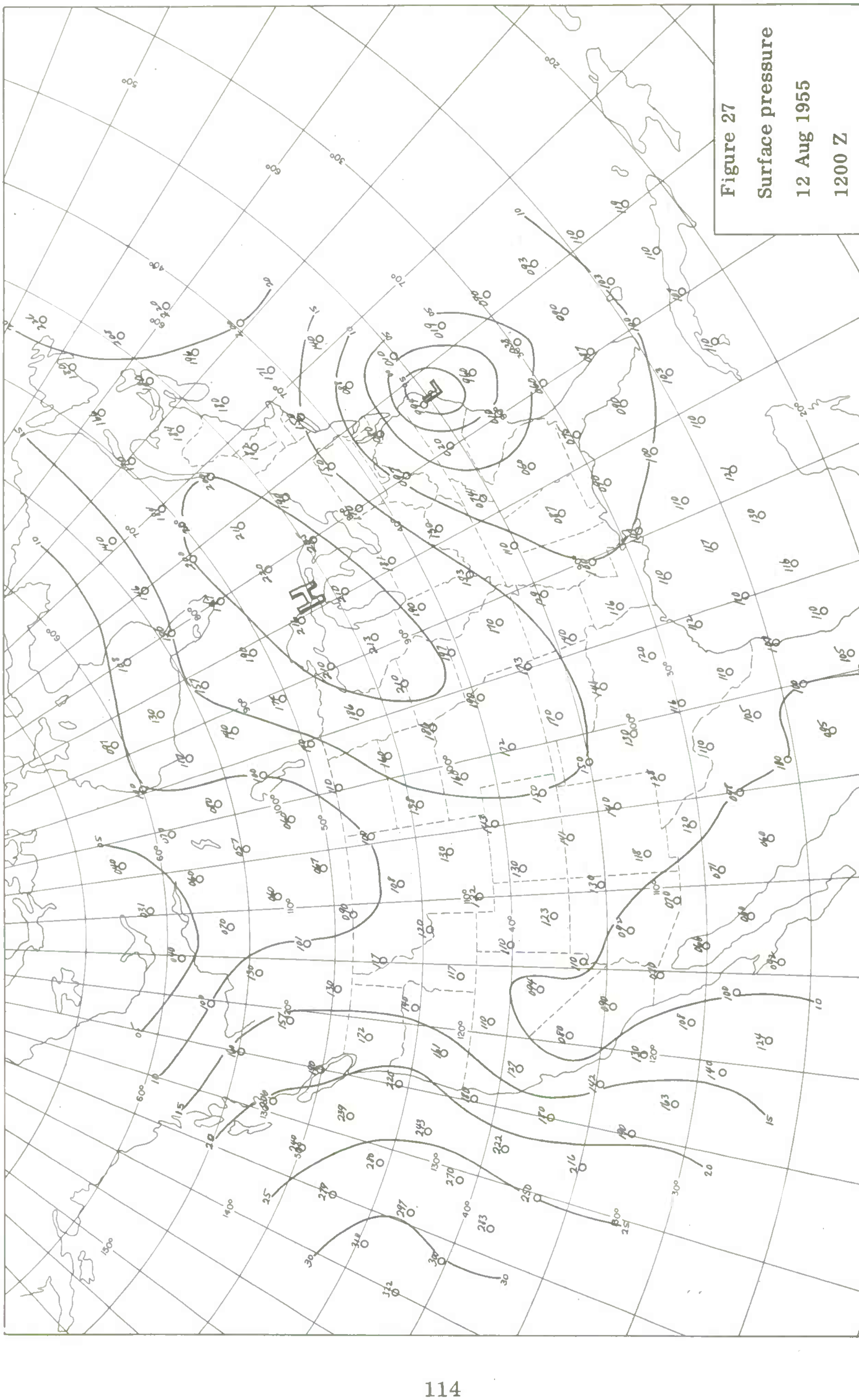


Figure 27
Surface pressure
12 Aug 1955
1200 Z

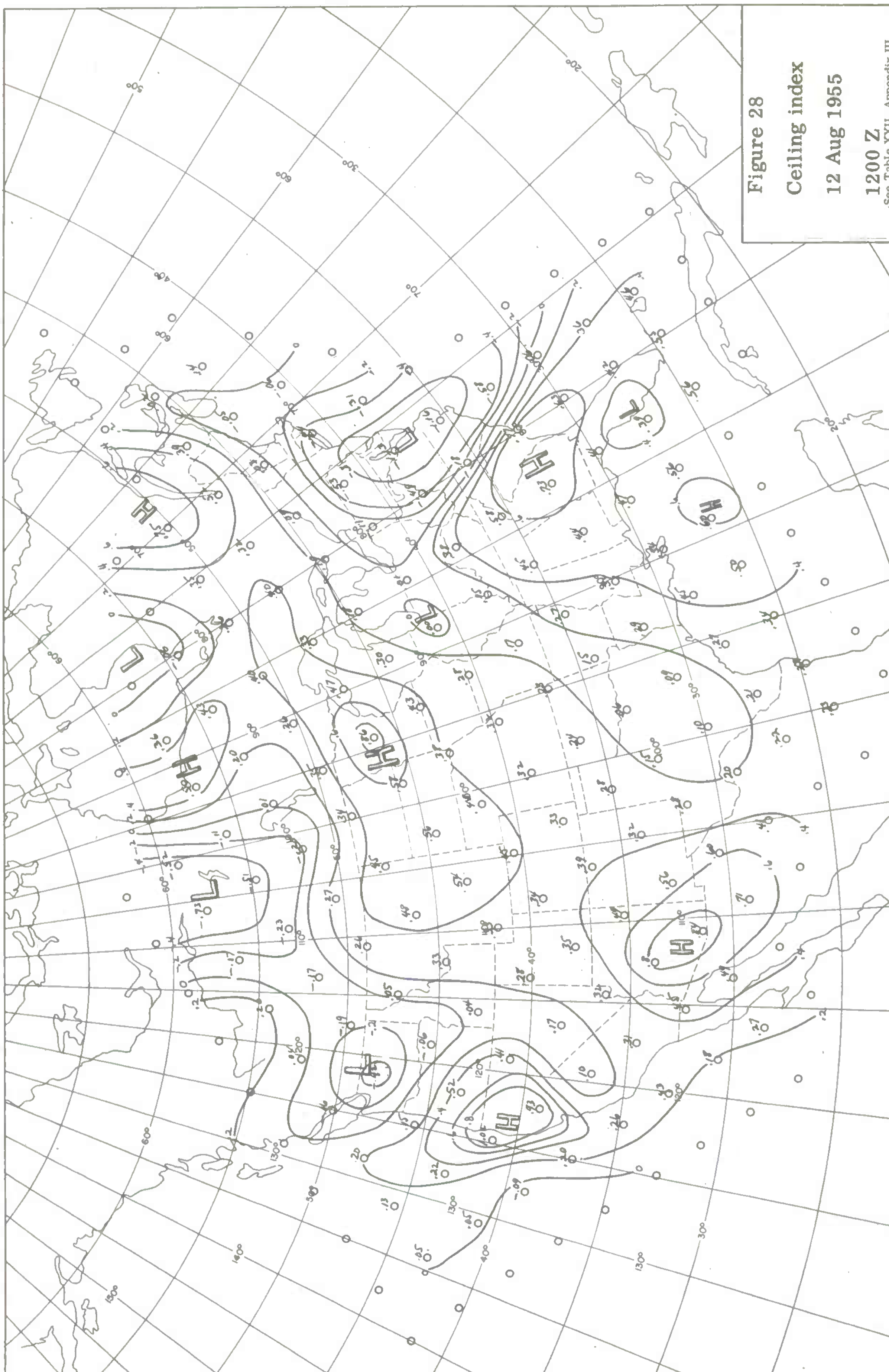


Figure 28
Ceiling index
12 Aug 1955
1200 Z
(See Table XXII, Appendix III

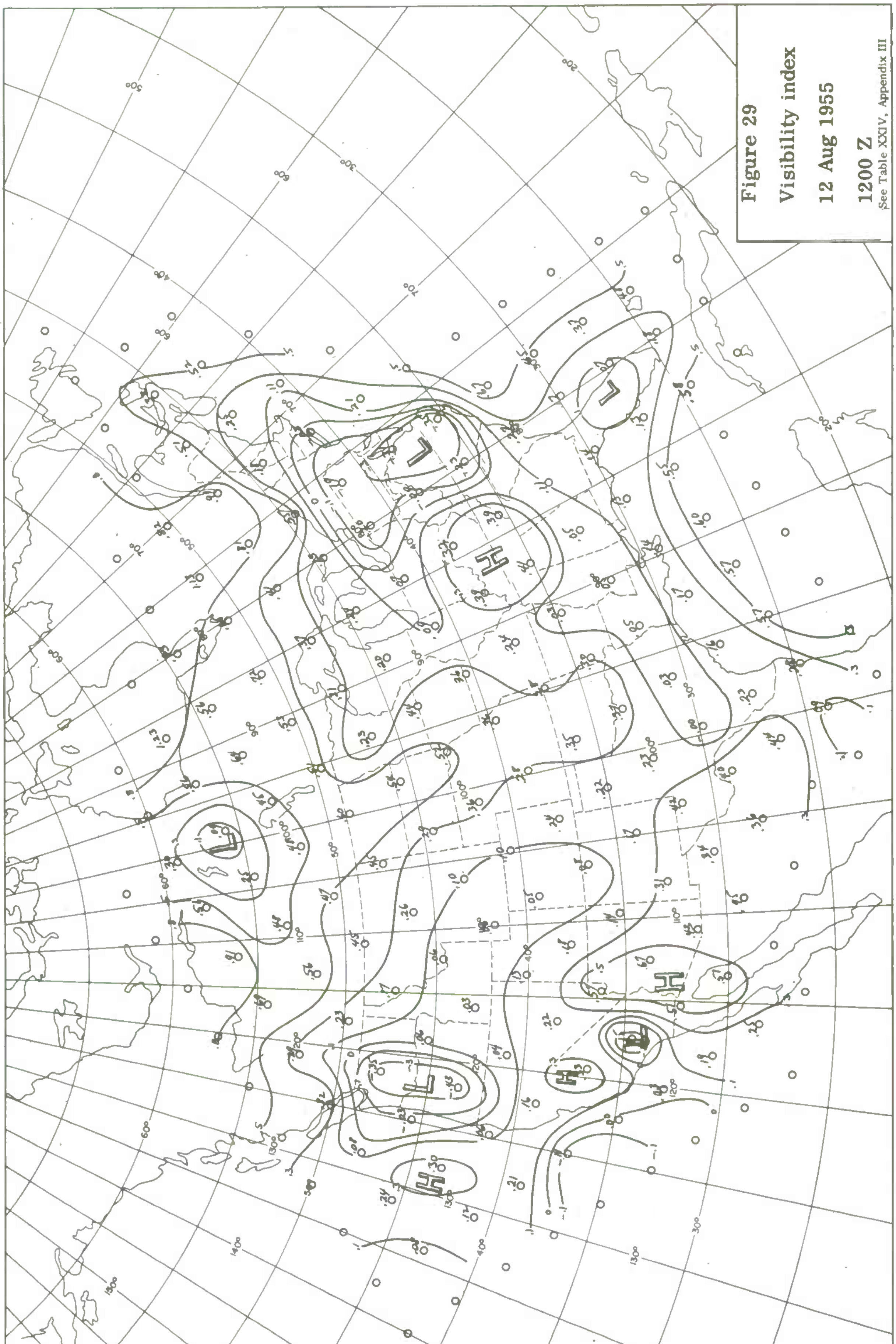


Figure 29
Visibility index
12 Aug 1955
1200 Z
See Table XXIV, Appendix III

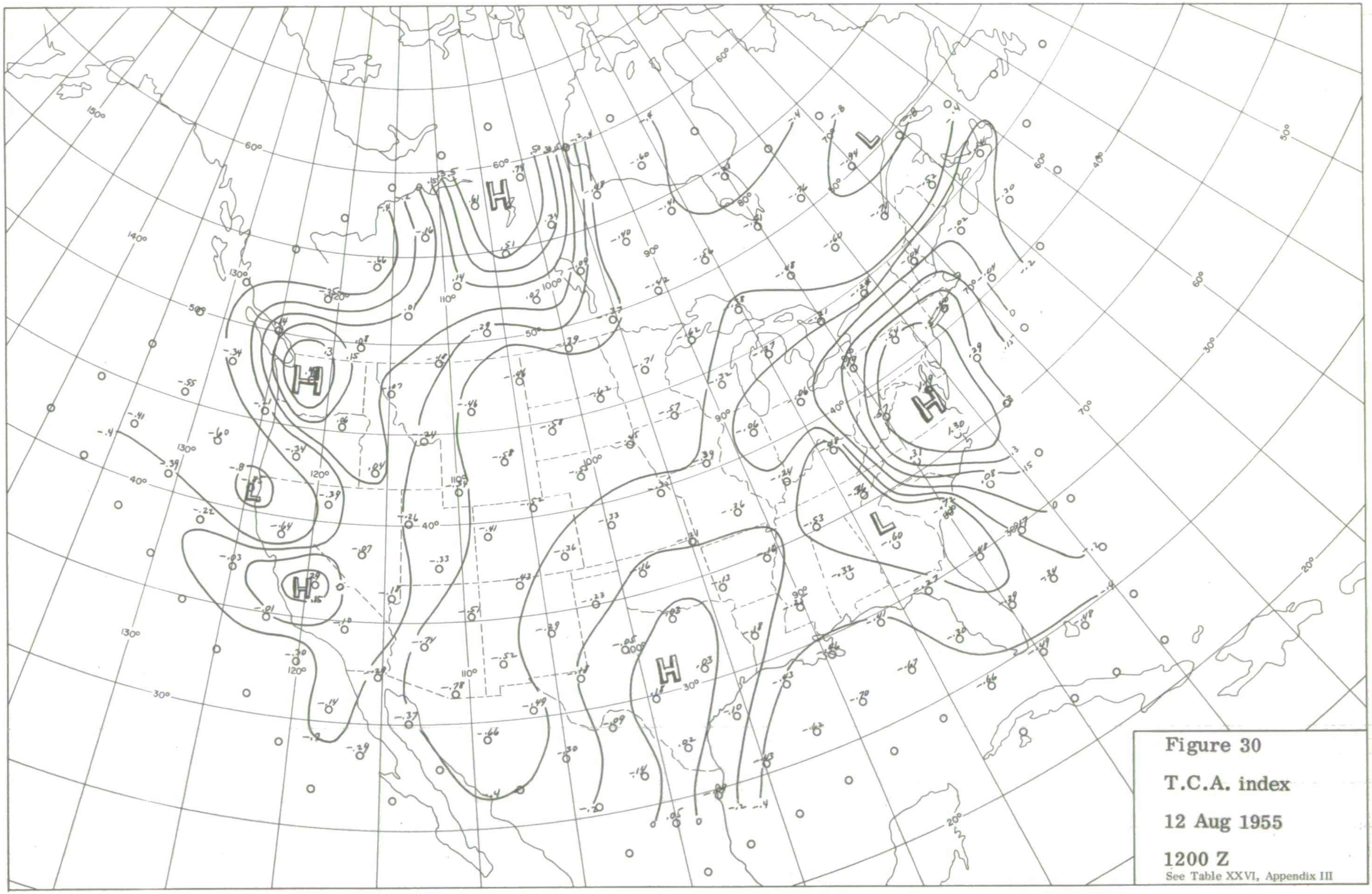


Figure 30
T.C.A. index
12 Aug 1955
1200 Z
See Table XXVI, Appendix III

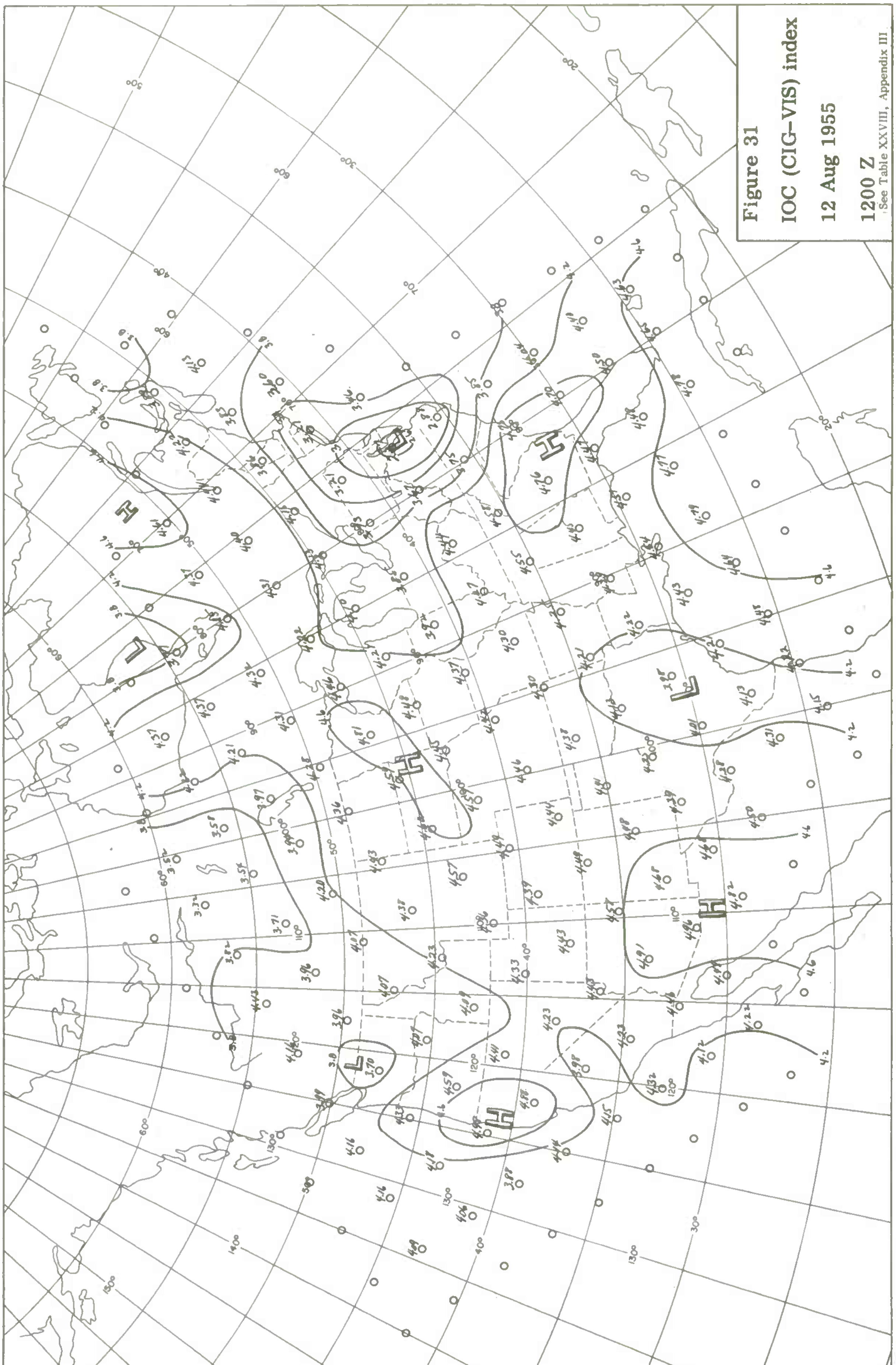


Figure 31
IOC (CIG–VIS) index
12 Aug 1955
1200 Z
(See Table XXVIII, Appendix III

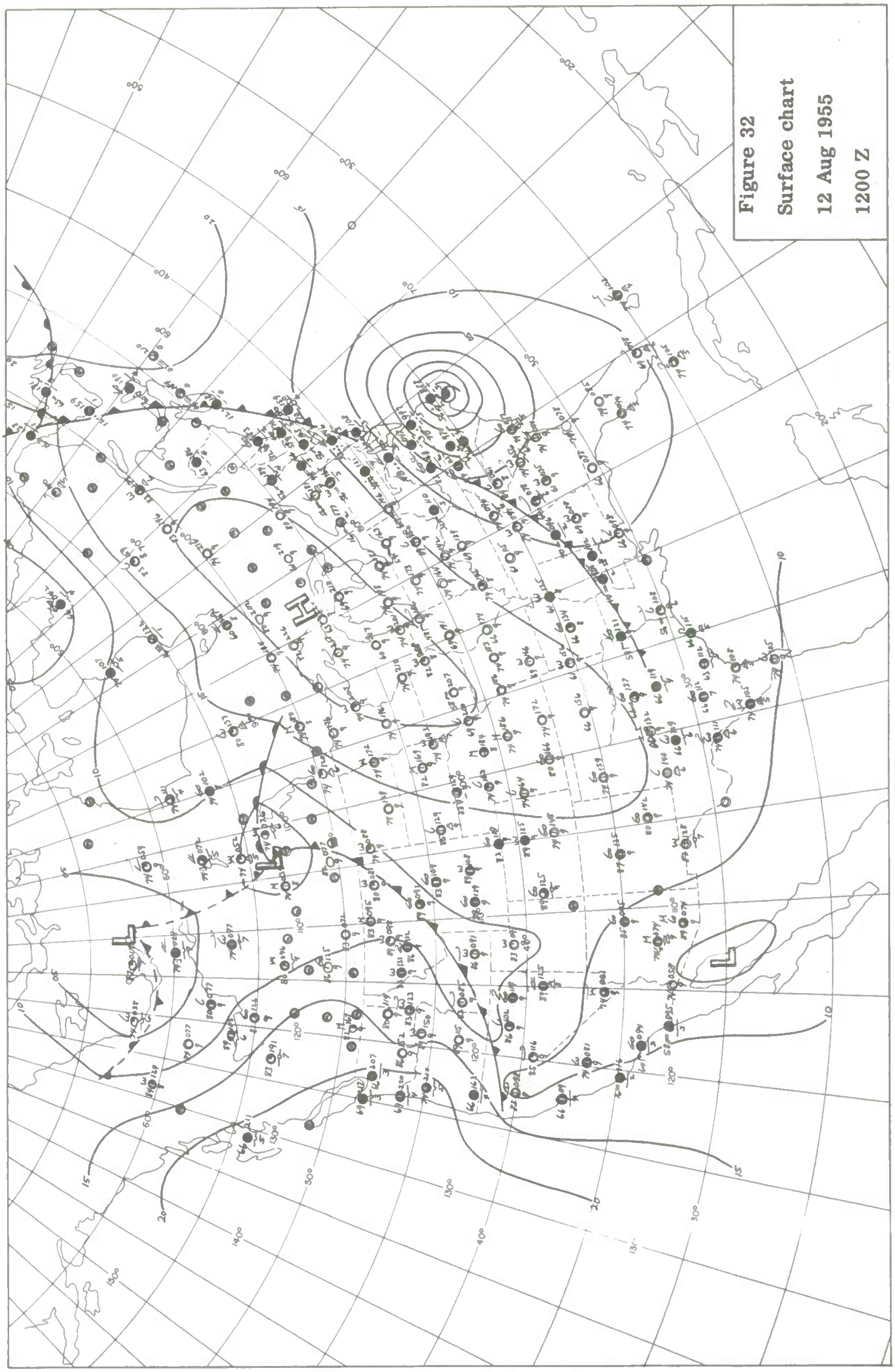


Figure 32
Surface chart
12 Aug 1955
1200 Z

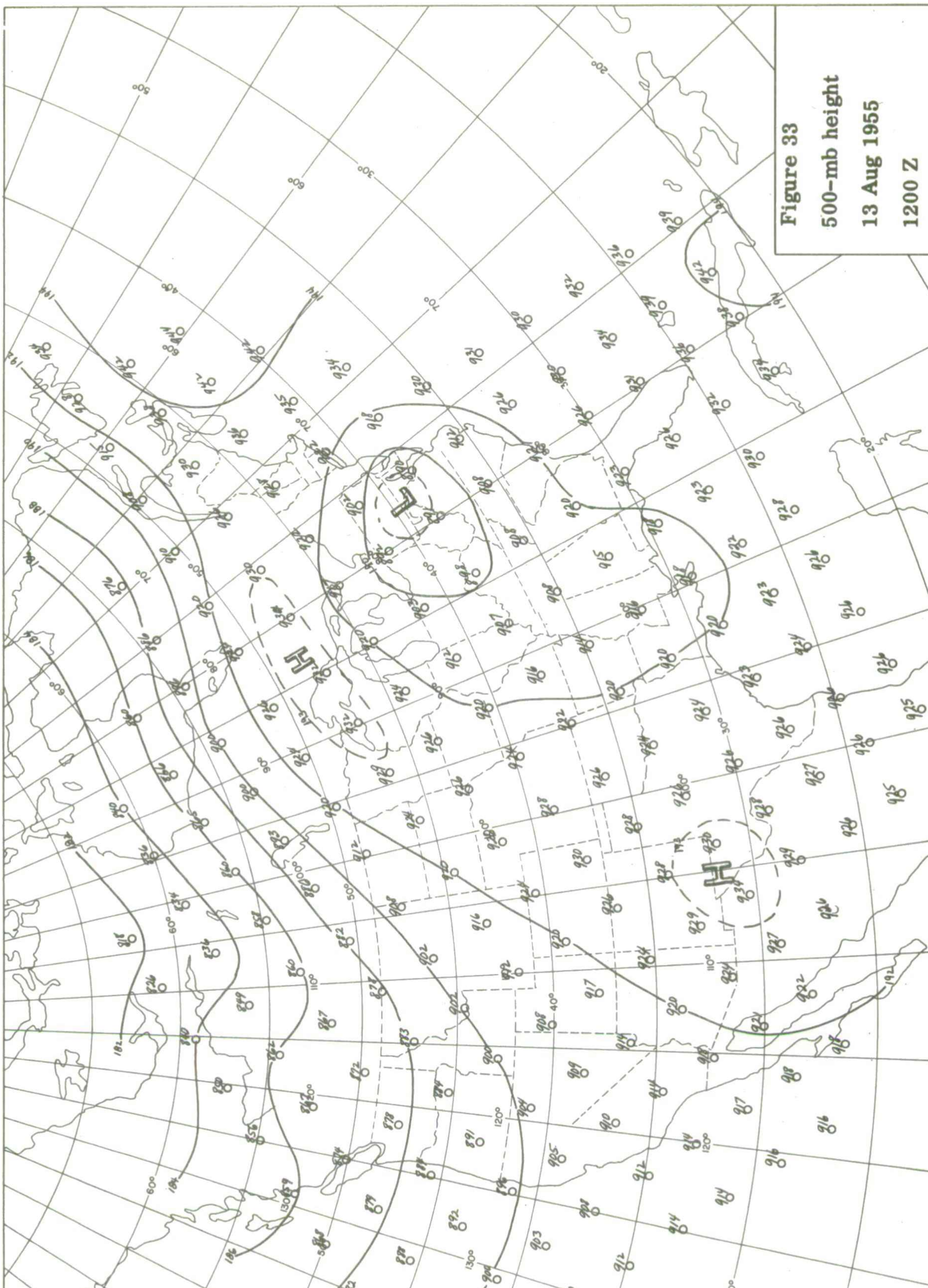


Figure 33
500-mb height
13 Aug 1955
1200 Z

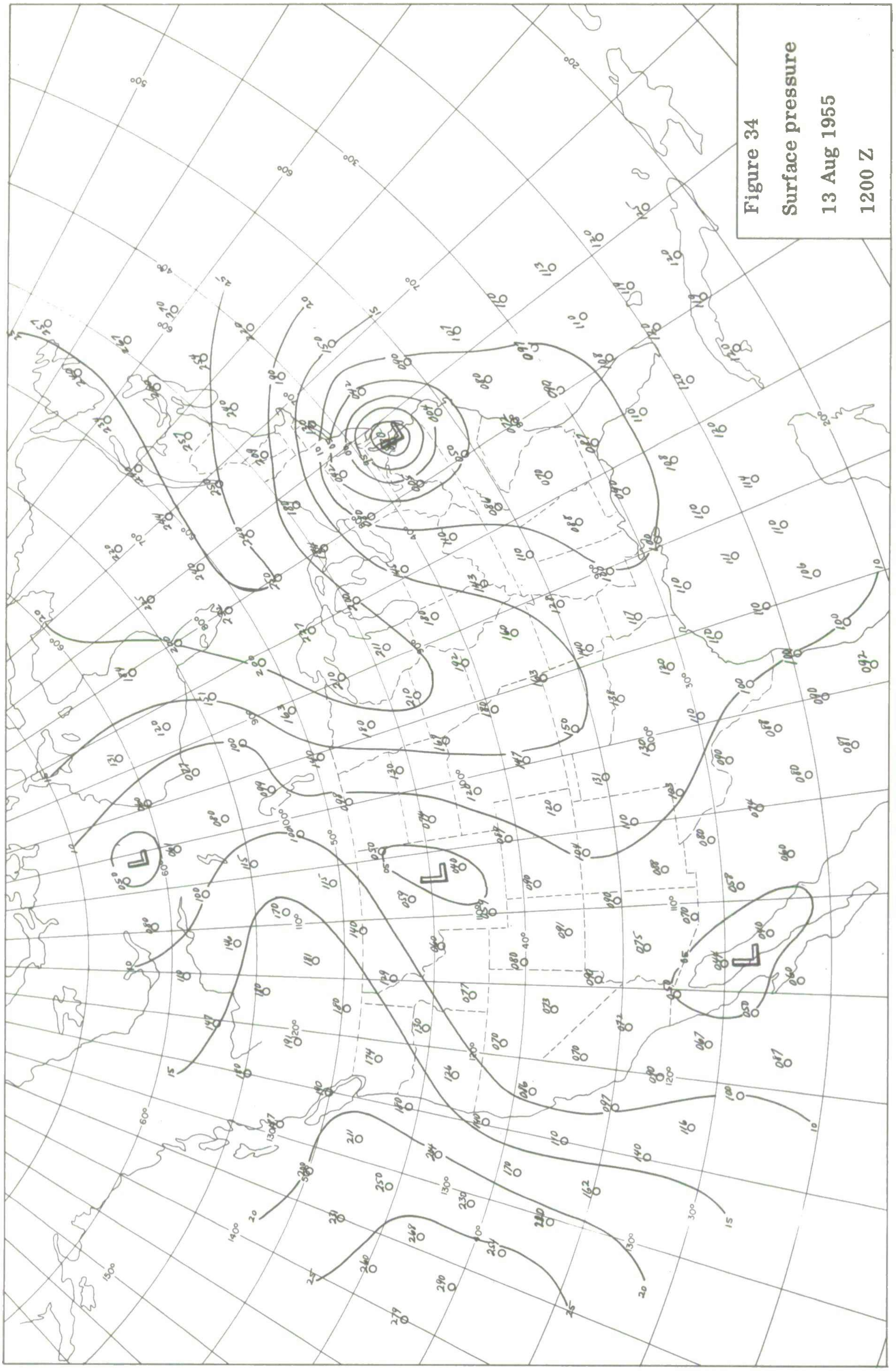


Figure 34
Surface pressure
13 Aug 1955
1200 Z

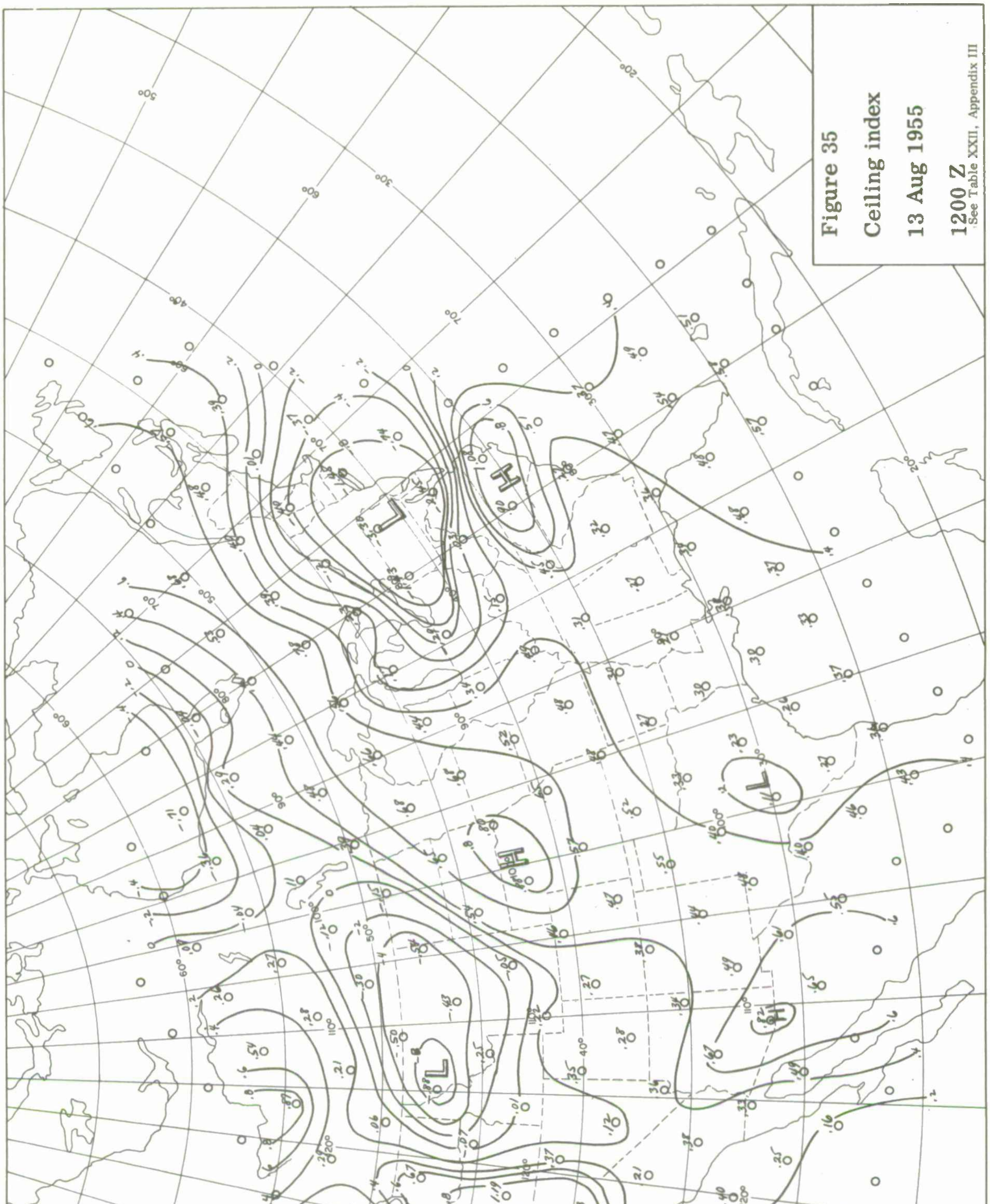


Figure 35
Ceiling index
13 Aug 1955
1200 Z
See Table XXII, Appendix III

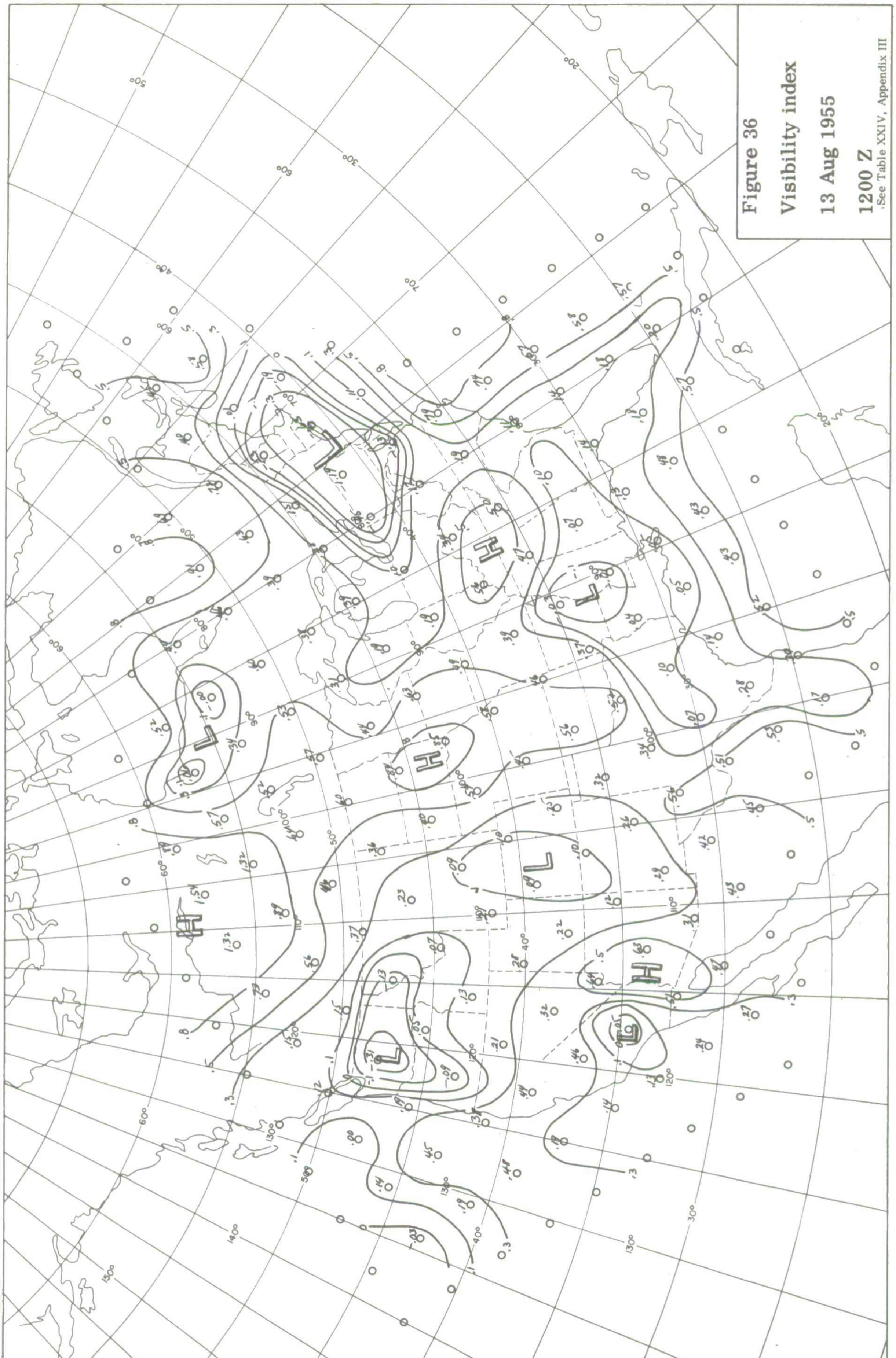


Figure 36

Visibility index

13 Aug 1955

1200 Z[1]

[1]See Table XXIV, Appendix III

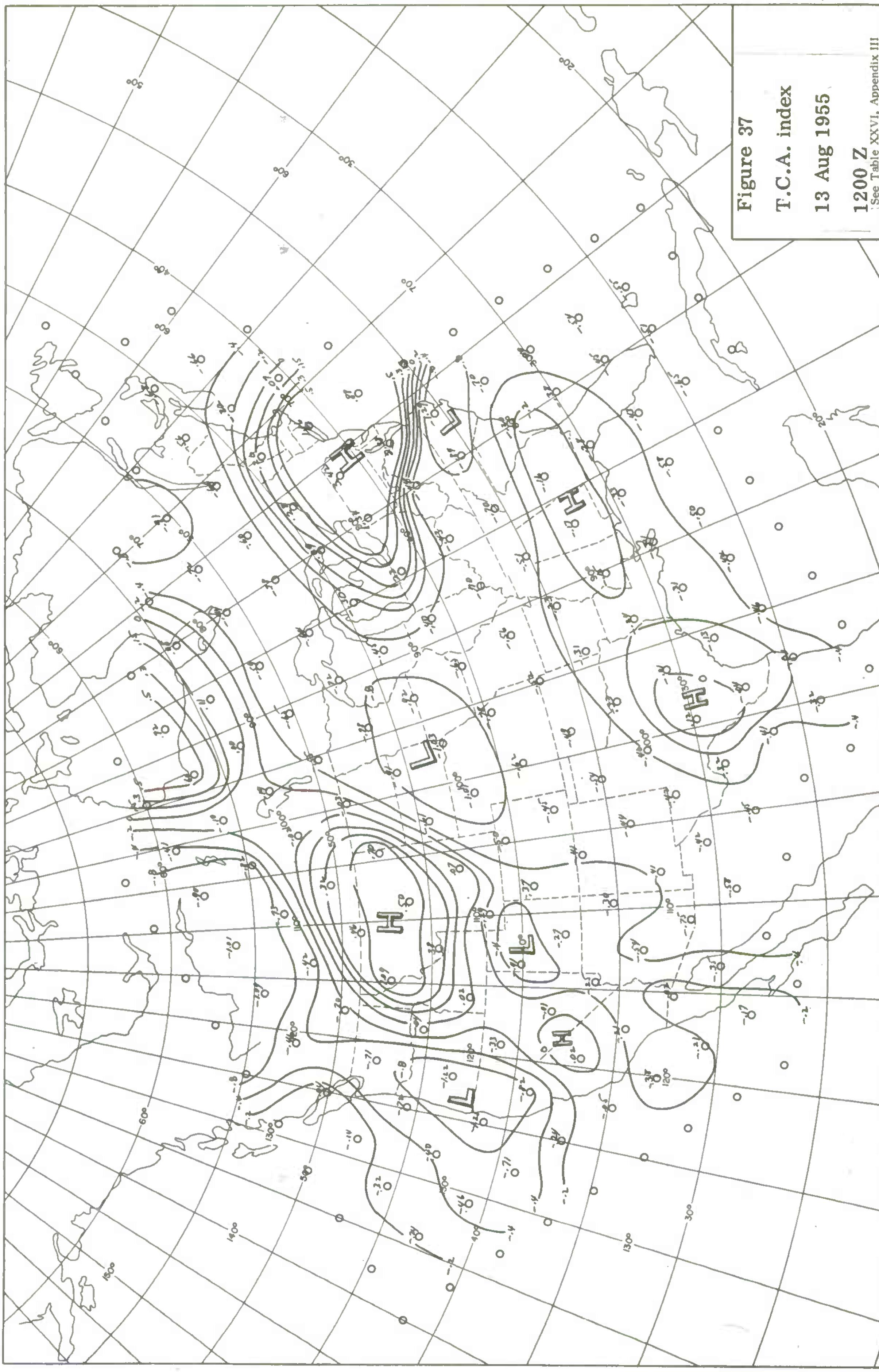


Figure 37
T.C.A. index
13 Aug 1955
1200 Z
(See Table XXVI, Appendix III

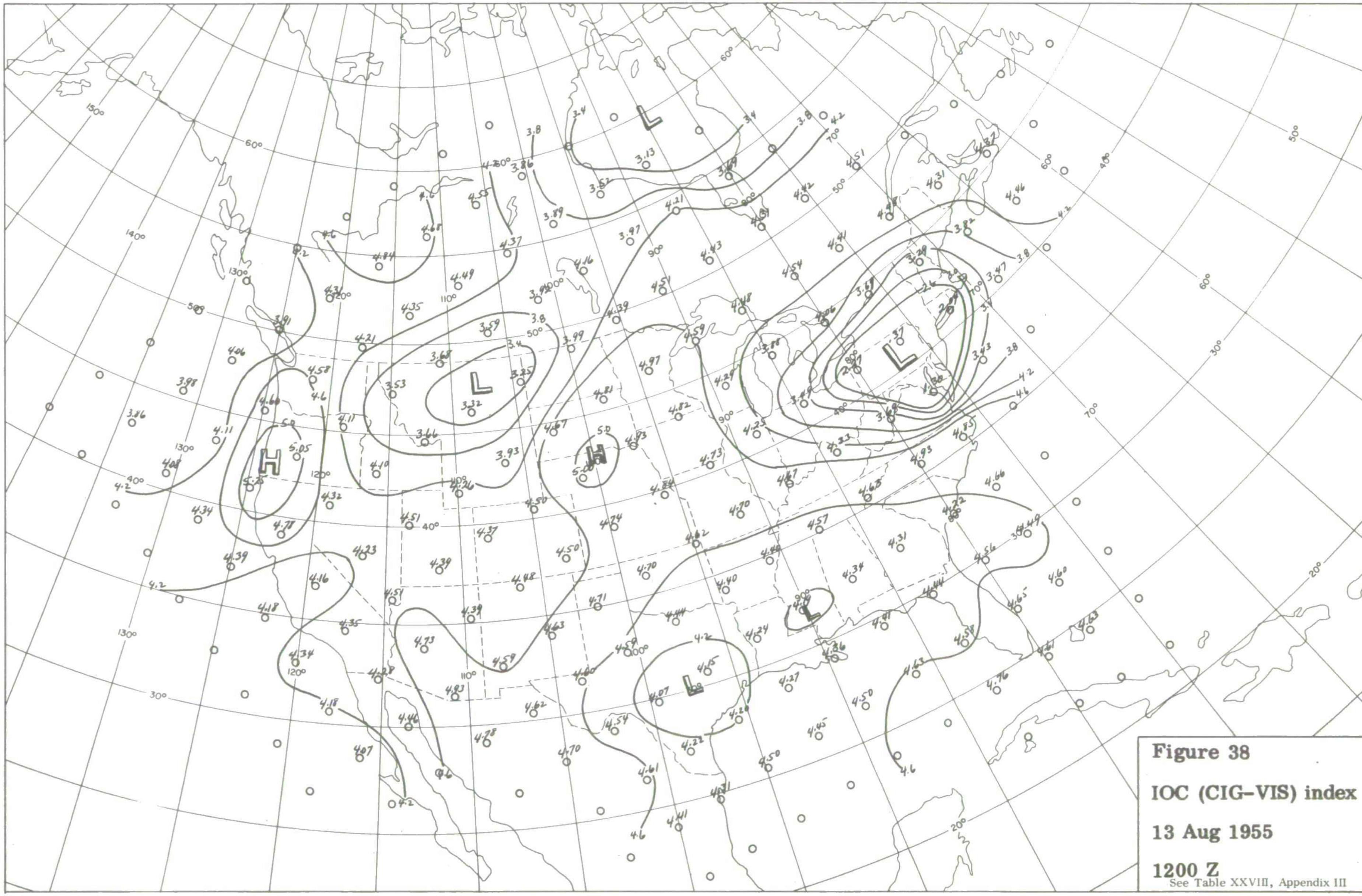


Figure 38

IOC (CIG–VIS) index

13 Aug 1955

1200 Z
See Table XXVIII, Appendix III

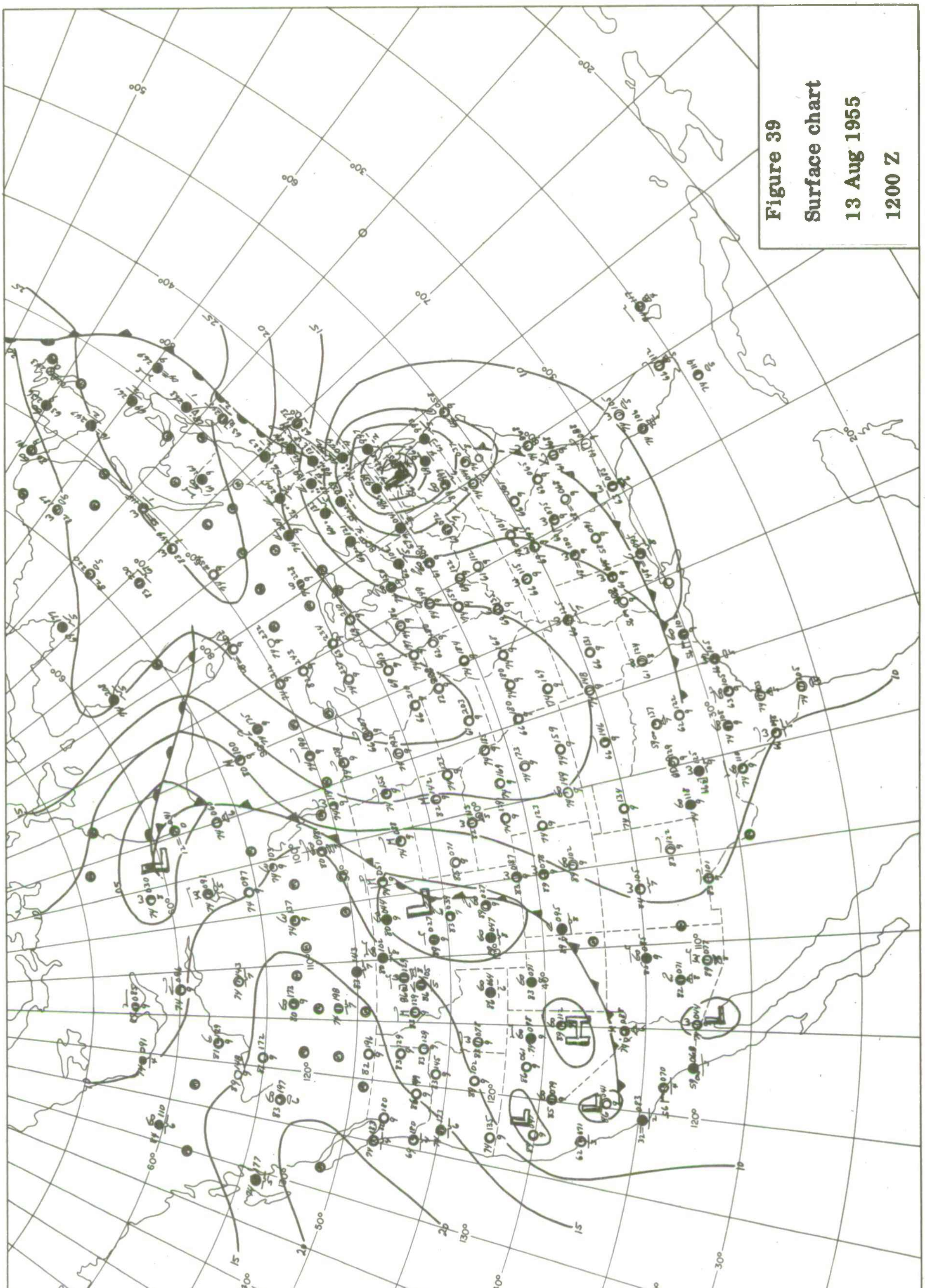


Figure 39
Surface chart
13 Aug 1955
1200 Z

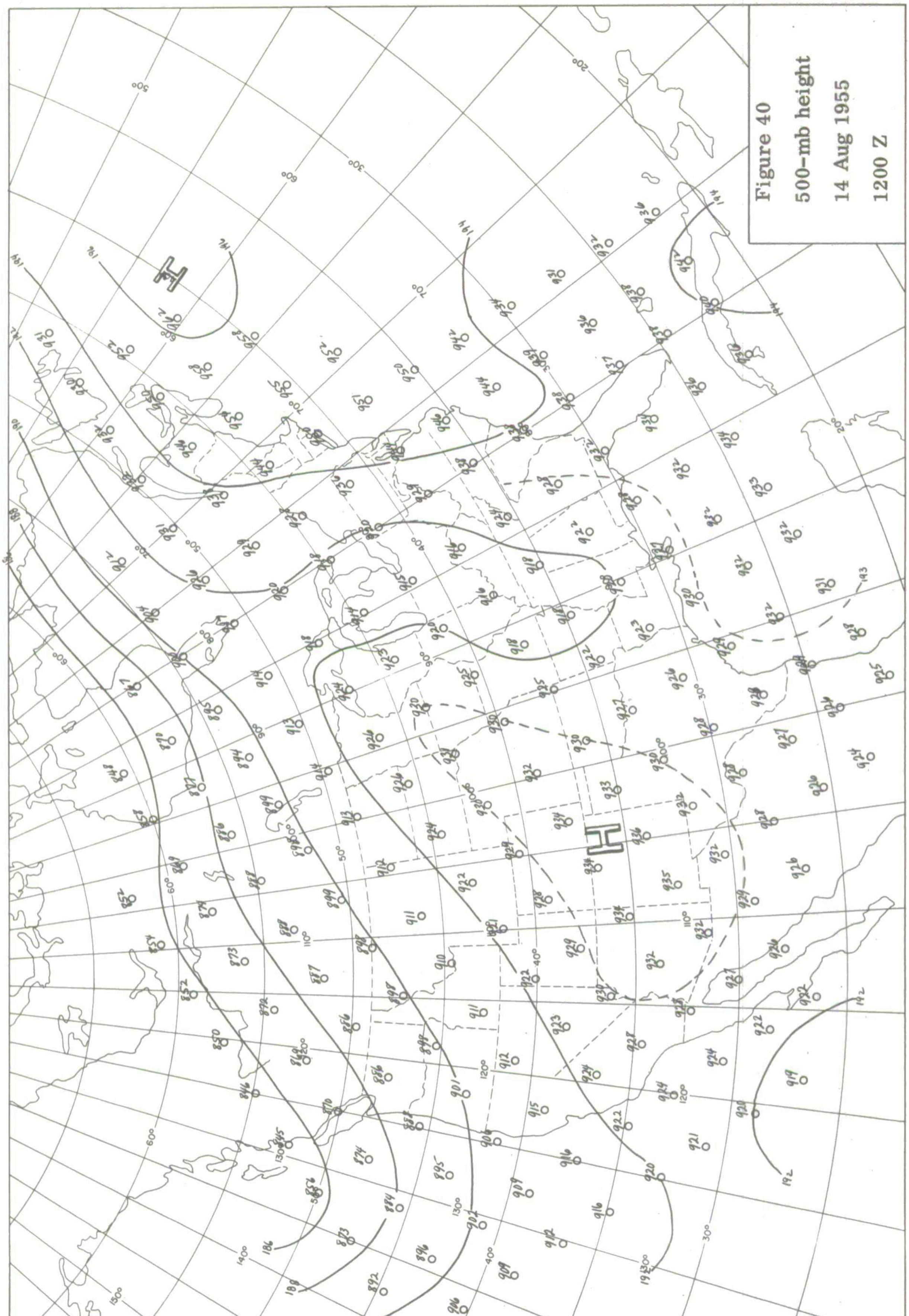


Figure 40
500-mb height
14 Aug 1955
1200 Z

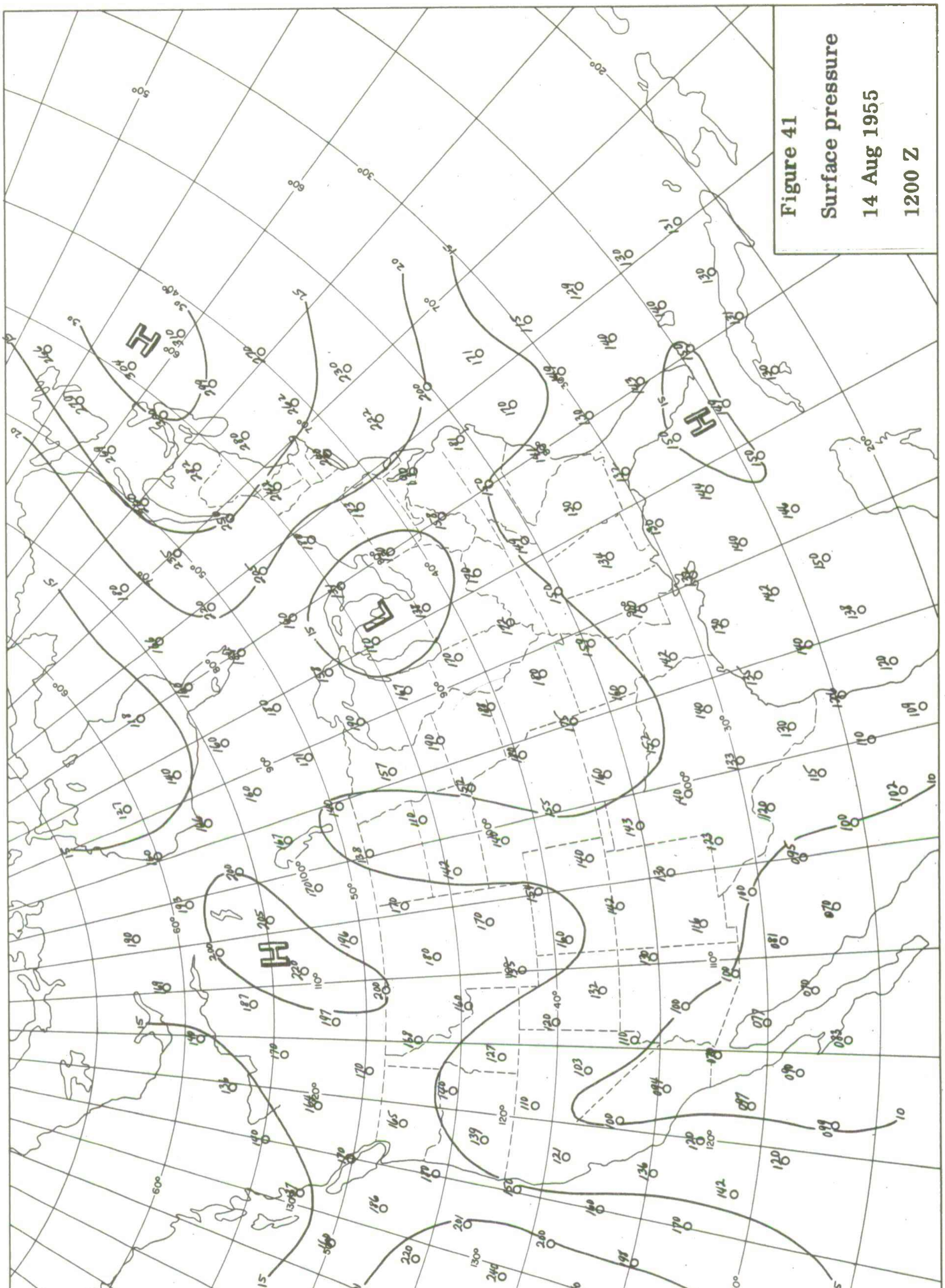


Figure 41
Surface pressure
14 Aug 1955
1200 Z

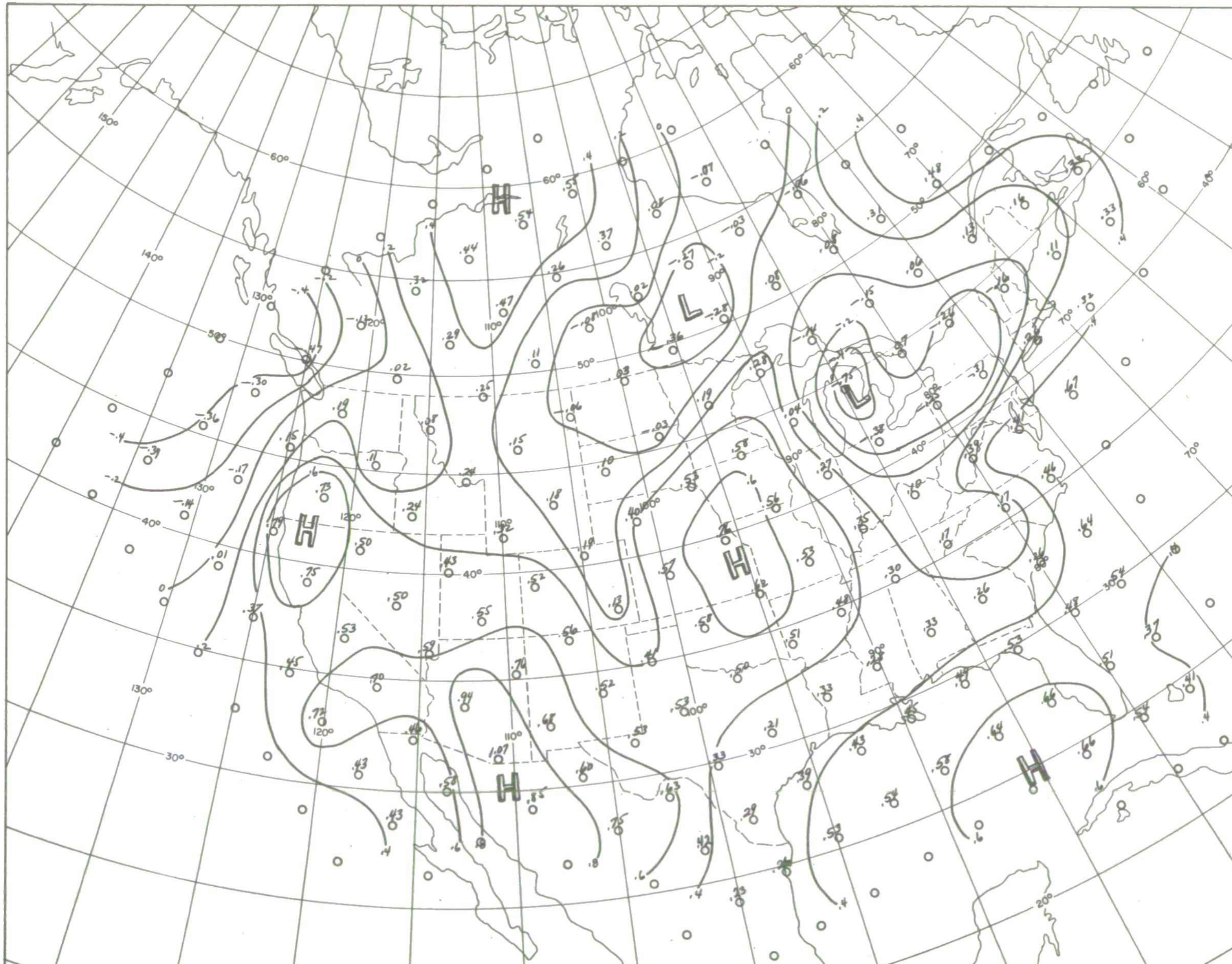


Figure 42
Ceiling index
14 Aug 1955
1200 Z
See Table XXII, Appendix III

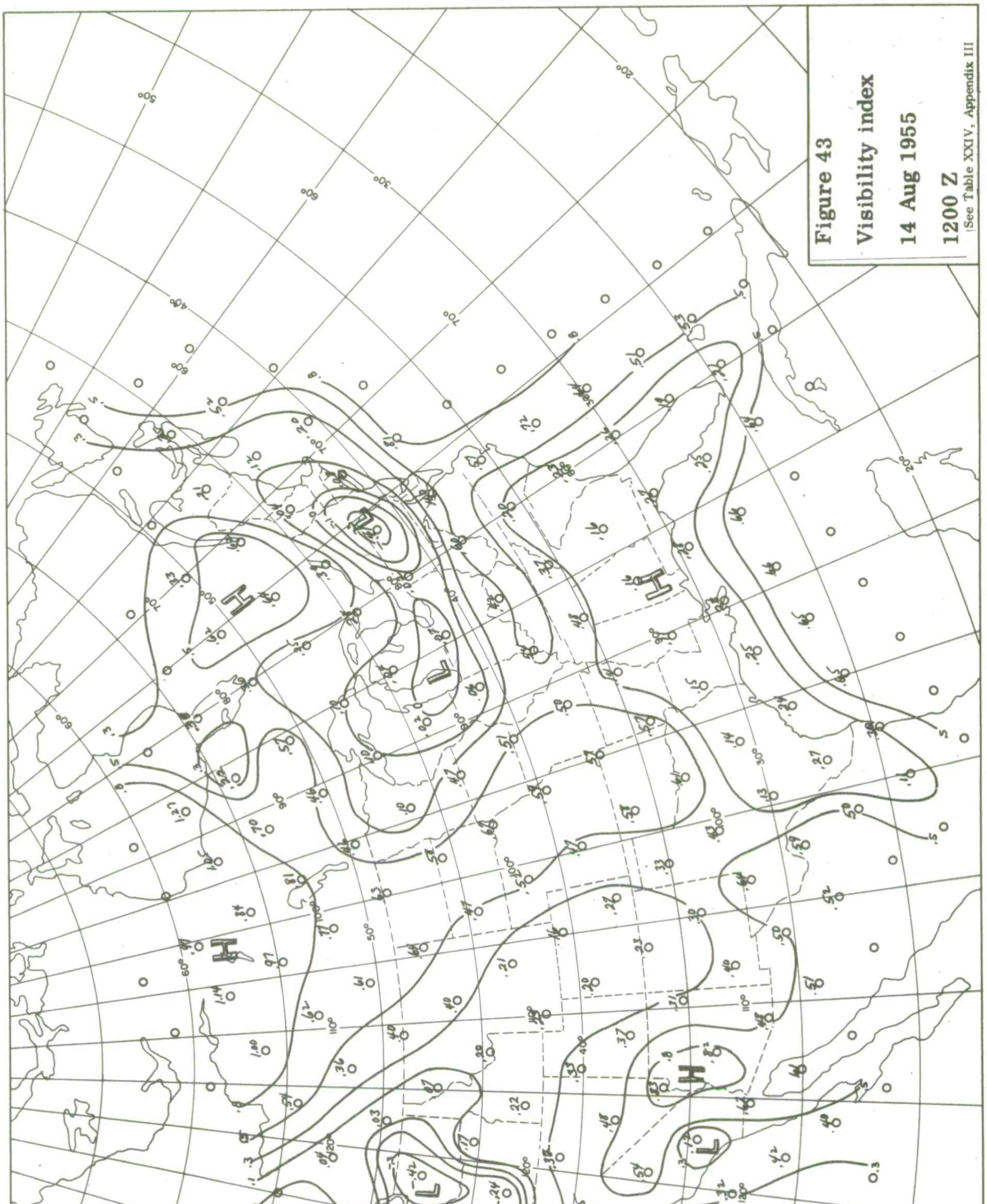


Figure 43
Visibility index
14 Aug 1955
1200 Z
See Table XXIV, Appendix III

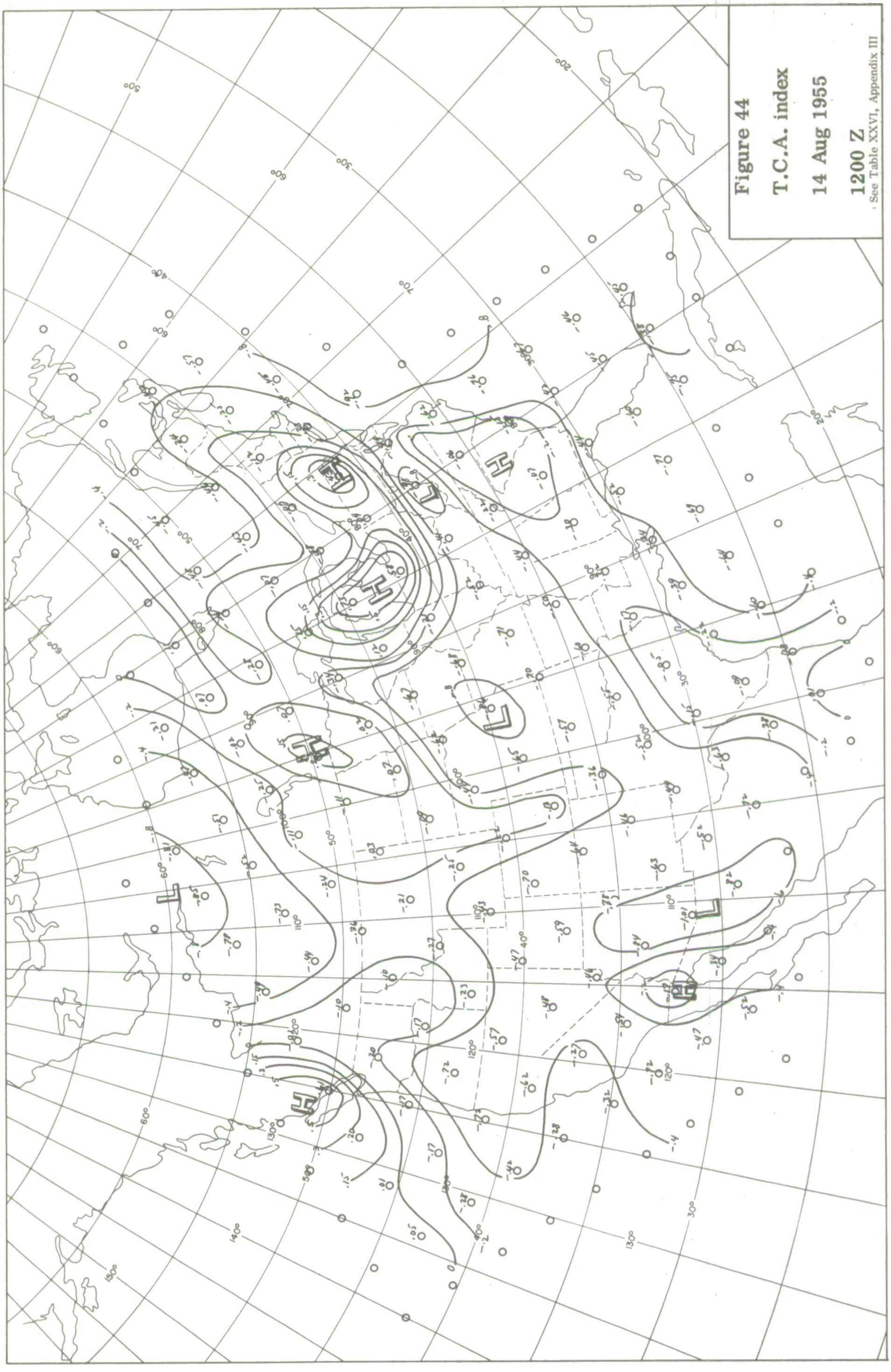


Figure 44
T.C.A. index
14 Aug 1955
1200 Z
' See Table XXVI, Appendix III

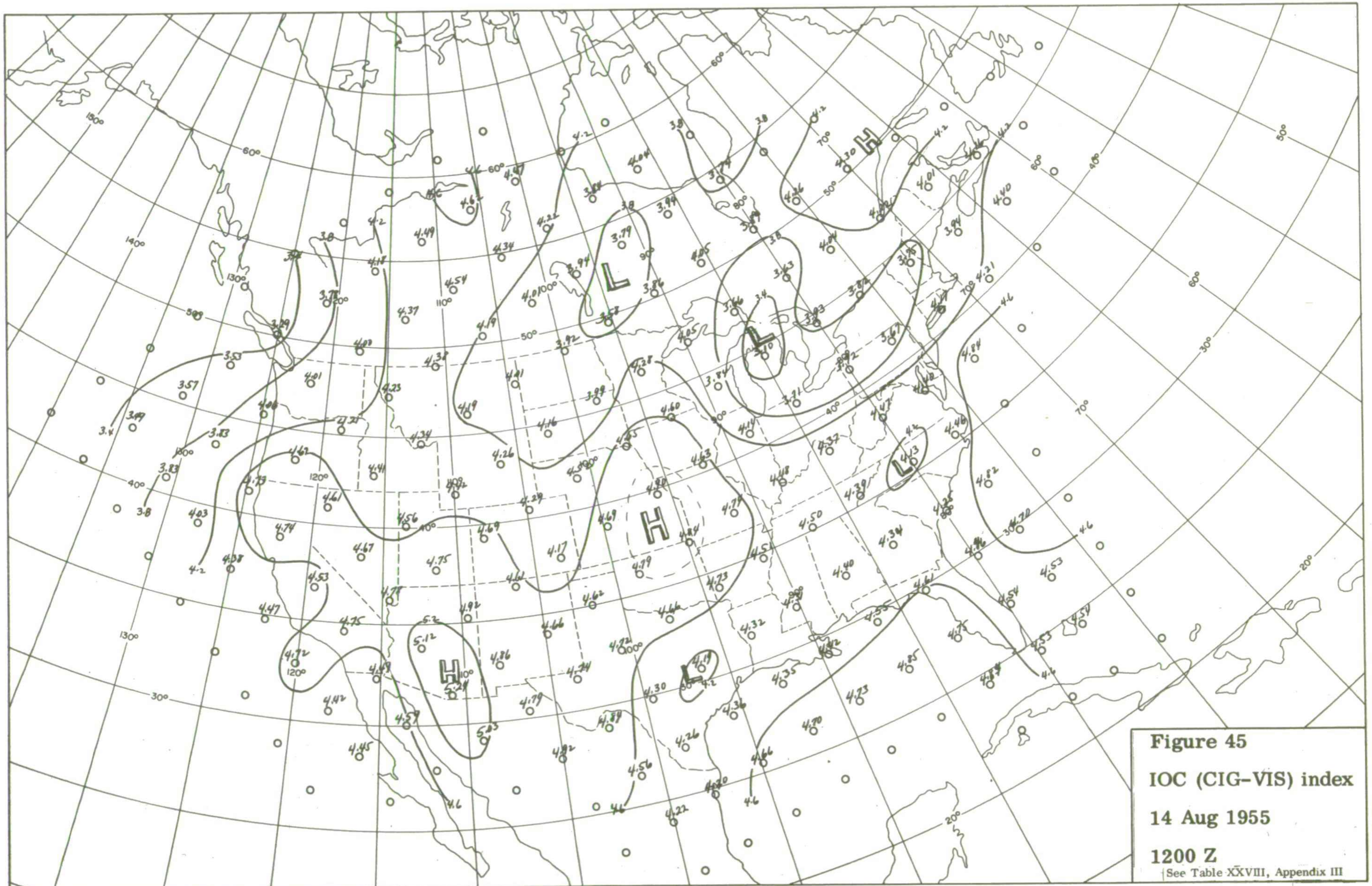


Figure 45

IOC (CIG–VIS) index

14 Aug 1955

1200 Z

†See Table XXVIII, Appendix III

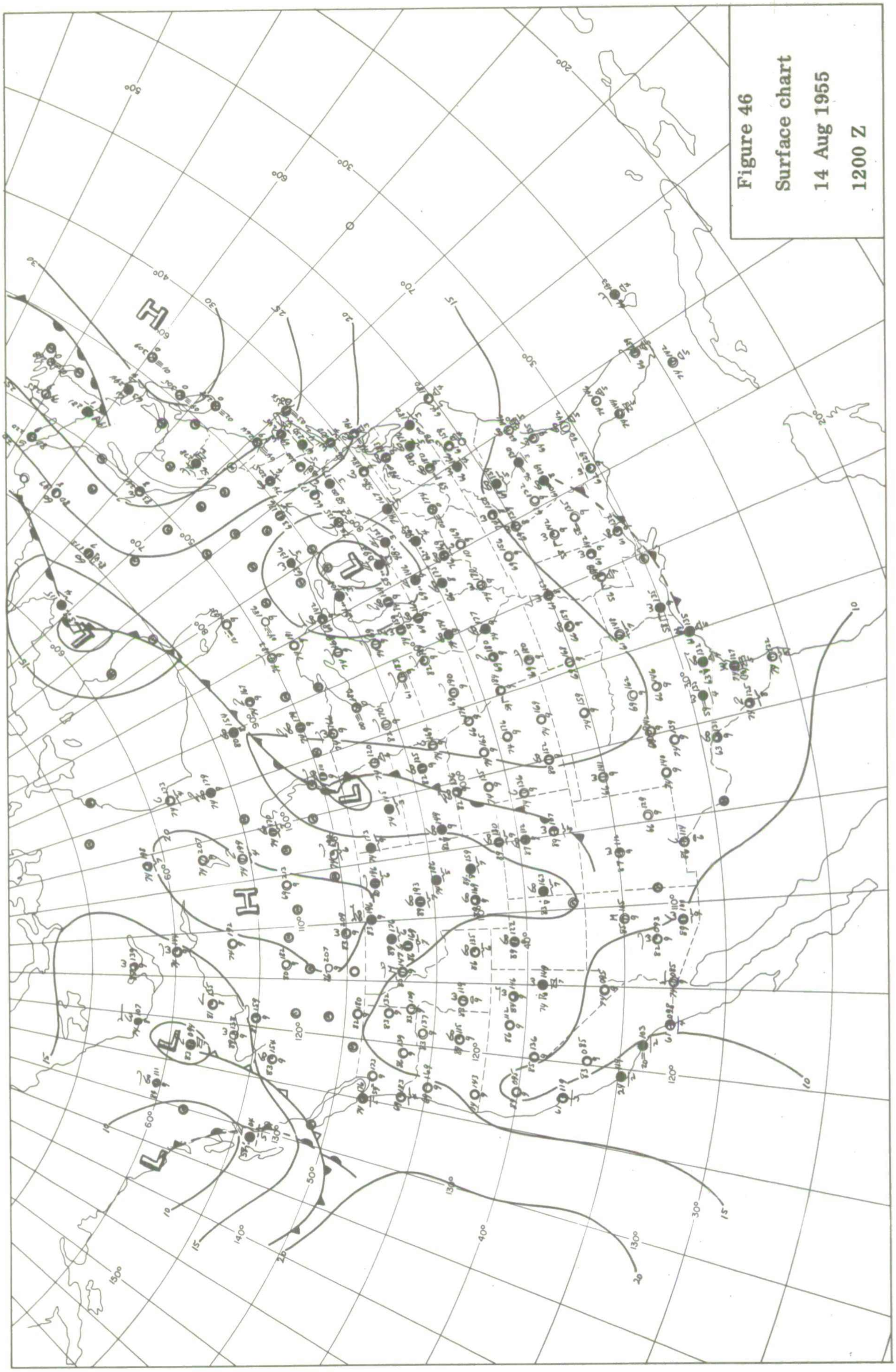


Figure 46
Surface chart
14 Aug 1955
1200 Z

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Security Classification

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13. ABSTRACT

Objective techniques are being developed for interpreting grid-point analyses and prognoses produced by computerized dynamical models in terms of concomitant surface-weather conditions. This Technical Report describes the project and work accomplished on it since May 1963.

Multiple regression equations were derived to express statistical relationships between surface-weather variables and derived upper-air parameters representing pertinent physical processes taking place between the surface and the 500-mb level. These upper-air (predictor) parameters were derived from observed height and thickness values and the climatological statistics of these values.

The work presently being conducted and plans for future work are discussed. Improvement is being sought by the definition of better predictor parameters to represent orographic effects and by the incorporation of moisture (cloud amount) information now available from dynamical models. The equations will be tested on real-time upper-air prognoses and readied for use in an operational test by the Air Weather Service by September 1965.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Ceiling						
Climatology						
Meteorological Parameters						
Rainfall						
Statistical Analysis						
Upper-atmosphere						
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